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Snow and Ice Accumulation Around Solar Collector Installations

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Sponsored by
Department of Energy
Office of Solar Applications
Washington, D.C. 20585

August 1979

Issued October 1979

Prepared for

Center for Building Technology
National Engineering Laboratory
National Bureau of Standards
U.S. Department of Commerce
Washington, D.C. 20234

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by

Michael J. O'Rourke

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FOREWORD

The Center for Building Technology (CBT) of the National Bureau of Standards (NBS) is conducting a project to develop improved technical data and design criteria relating to the structural performance of solar collectors and collector arrays, including their supports and fastening devices. An important element of this project is concerned with the effect of snow and ice on solar collectors, their support systems, and the buildings that they are placed on.

Practically no data exists regarding the accumulation of snow and ice at solar collector installations. Work on design criteria is only at the exploratory stage, yet it must proceed rapidly because of the increasing number of buildings with solar collector installations. This report and a companion report, "Snow and Ice Accumulation at Solar Collector Installations in the Chicago Metropolitan Area"[1/] represent the initial data collection in this effort. Preliminary design recommendations are now being formulated at NBS, and your comment relevant to this report or to the general problem is welcome.

James Robert Harris
Center for Building Technology
National Bureau of Standards
Washington, D.C. 20234

1/ by Ross B. Corotis, Charles H. Dowding, and Edwin C. Rossow. Published as NBS-GCR 79 181 and available through the National Technical Information Service (NTIS), Springfield, VA 22161

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Section 1

INTRODUCTION

The purpose of the research project described in this report is to measure snow and ice accumulation around solar collectors and then analyze the data to determine the effect of snow and ice on the structural performance of the collectors and their supports. The field data was gathered from eight structures with solar collectors on their roofs during the first three months of 1979.

There are three other sections to this report. In Section 2, State of the Art procedures for determining snow loads on structures are reviewed. In this section, methods used to estimate the maximum ground loads are described and the factors which influence the ratio between the snow on the roof and the snow on the ground (ground to roof conversion factor) are enumerated. Also, the important problem of nonuniform and drifting roof snow is discussed. Finally, information on the dollar damage associated with structural failures due to snow is reviewed. This damage data, which was gathered from insurance companies, point up the importance of drifting roof snow vis-a-vis collapse.

The third section of the report describes the data collection and subsequent analysis, and presents the results of the study. The structures used in the study as well as the data gathering procedure are described in detail. Also, interviews with owners of the structures about the snow and ice accumulation on their solar collector installations are presented in Section 3.

A summary of research results pertaining to snow loads on solar collectors and their supporting structure is presented in the final section along with suggestions for future research.

Section 2

STATE OF THE ART - SNOW LOADS

GROUND SNOW LOADS

In order to establish a design snow load for a roof, one must have some idea of the expected amount of ground snow. This is usually quantified by the maximum annual ground snow load corresponding to a particular mean return period. Boyd (3) for example, has used the annual maximum ground snow depth for over 200 locations in Canada to obtain ground snow depths with a 30 year mean return period. Thom (16) has used a log-normal extreme value distribution to fit the annual maximum water equivalent ground snow for the contiguous United States. Tobiasson and Redfield (17) used a log-normal extreme value distribution to establish ground snow loads with 25, 50 and 100 year mean return periods for about 140 locations in the state of Alaska. Ghiocel and Lungu (5) have used a Gumbel extreme value distribution to fit the maximum annual snow depths for Bucharest. While it is true that different extreme value distributions (log-normal vs. Gumbel, for example) yield different ground snow loads corresponding to the same mean return period, the differences are relatively small.

While the procedures outlined above seem fairly straight forward, there are complications. These complications are due to the fact that some weather recording stations in the U.S. and elsewhere measure the water equivalent of the snow, while other stations measure only the snow depth. For stations with water equivalent, ground loads in lbs. per square foot are easily developed by multiplying the water equivalent in inches by 62.4/12. However, for stations where only ground depth is recorded, a density is necessary to calculate the load. Ghiocel and Lungu (5), Boyd (3) and Anderson (2) have

proposed using an average snow density for calculation of the maximum ground snow load. Noting that the maximum ground snow load and the maximum ground depth often occur at different times during the winter, Tobiasson and Redfield (17) propose using a conversion density. This conversion density is neither the maximum snow density nor the density corresponding to the maximum snow depth, but a density which when multiplied by the maximum depth yields the maximum ground load.

CONVERSION FACTOR

For the structural design of a roof system, the engineer is interested in the intensity and distribution of snow loads on the roof. These roof loads are related to the ground snow load through the ground to roof conversion factor C_f. The design snow load for a roof is obtained by multiplying the design ground load by C_f.

Both the 1970 Canadian National Building Code (10) and the American National Standards Building Code Requirements (1) recommend a basic conversion factor of 0.8 for sheltered roofs. This value is reduced by 25% for roofs fully exposed to high velocity wind (i.e., $C_f = 0.6$). A similar reduction for wind swept structures is recommended by Tobiasson and Redfield (17) for structures in Alaska.

In a number of studies one can find mentioned the main parameters which effect the ground to roof conversion factor. These parameters are:

... wind exposure and environment

... thermal characteristics of roof and structure

... roof slope

... type of winter

The effect of these parameters will be reviewed in the following paragraphs. For a more detailed discussion see O'Rourke (13).

To be consistant and not overly conservative, a design conversion factor for a given environment should be the best estimate of the ratio between the maximum uniform roof load during the winter and the maximum ground load during the winter. Note that the maximum roof snow load does not necessarily occur at the same time as the maximum ground snow load. For wind swept structures in regions with winter-long accumulation, the maximum roof load generally occurs immediately after a large snowfall, possibly towards the beginning of the winter, while the ground snow load would reach a maximum towards the end of the winter. For sheltered structures, the maximum roof load is generally due to an accumulation of snow over the winter and many times occurs towards the end of the winter when the ground snow load is also a maximum.

As alluded to in the previous paragraph, wind action can redistribute and/or remove a substantial portion of the roof snow. Because of this, the roof's wind environment is one of the most important parameters affecting the ground to roof conversion factor. There are two elements which determine the ability of wind to remove snow from a roof. The exposure of the roof to wind (i.e., windswept, semi-sheltered or sheltered) is the first of these parameters. The wind exposure ratings are functions of the relative locations of the roof with respect to trees and other wind breaks. It should be noted that these ratings are subjective measures. Two individuals could classify the same structure differently. The second element comrising the wind environment is the wind speed in the general area of the structure during the winter season. Ghiocal and Lungu (5) cite work done in Russia which indicates that the following relationship exists between

the conversion factor and wind speed

$$C_f = 1.26 - 0.13\ \bar{v}$$

where $\bar{v}$ is the average wind velocity during the winter in meters per second. O'Rourke (13,14) presents a similar relationship for the effect of wind speed and exposure upon the conversion factor.

Intutitively, the slope of the roof should have an effect upon the conversion factor; the larger the slope, the smaller the conversion factor. Both the Canadian (10) and ANSI (1) codes allow no reduction in the basic conversion factor for roofs with slopes less than 30^{o}, a straight line reduction between 30^{o} and 60^{o}, and a conversion factor of 0.0 for slopes of 60^{o} or greater. Analysis of snow load case histories gathered during the 1975-76 and 1976-77 winters (13), indicate that for roof slopes less than 30^{o}, slope has no observable effect upon the conversion factor, which tends to confirm the approach taken by the codes.

The conversion factor for a structure is effected by its thermal characteristics and, in particular, the roof's R value or resistance to heat flow. If the structure is heated and has a low R-value, thermal energy can flow through the roof causing roof snow to melt and hence reduce the conversion factor. If, on the other hand, the structure is unheated, or heavily insulated (i.e., high R value) then less thermal energy can flow through the roof and less roof snow can melt. This effect can easily be noted by observing the differences in roof snow for a heated house and an attached unheated garage. Quantification of this effect requires a comparison of the conversion factors for structures which are similar in all aspects except for the thermal characteristics. Unfortunately, precise relationships between a structures thermal characteristics and the conversion factor cannot

be established at the present time due to insufficient data.

Another parameter which also effects the design conversion factor is the type of winter or the typical snow fall pattern during the winter. Consider location A where the winter is typically characterized by a few snowfalls separated by warmer weather. In this case, there will be little or no accumulation of ground snow from one snowfall to another, and each snowfall would essentially correspond to snow falling on bare ground. For this location both the maximum ground load and the maximum roof load would occur at the largest snowfall and hence the design ground to roof conversion factor would be relatively close to one. Now consider a semi-sheltered structure at location B where the winter is typically characterized by a large number of snowfalls closely spaced in time throughout the winter. For this location, a maximum ground load is due to an accumulation throughout the winter while the maximum roof load is due to the same accumulation modified by wind, thermal and other effects. For location B, the design conversion factor, that is, the maximum roof load divided by the maximum ground load would be substantially less than that for location A. The author (14) has suggested that differences in the measured and design conversion factor for Albany, New York, and for a location in the Adirondack Mountains in upstate New York can be explained by the differences in the typical pattern of snowfall at these two separate locations.

NONUNIFORM LOADS

The total design load on a roof can theoretically be calculated knowing the conversion factor and design ground snow load. However, structural design of a roof system requires knowledge of the distribution of the load as well as its total magnitude. In general, if the winds during and after the snow-

falls are mild or the roof is sheltered from the wind, the distribution of the snow on the roof will be essentially uniform. However, if the roof is exposed to relatively strong winds, drifting or redistribution of the roof snow can occur. One type of drifting occurs on roofs with parapet walls or on structures with roofs at different elevations. A typical example of this type of drifting due to different elevation was recorded in reference (12). For this particular structure, the average roof and ground depths were 4 and 8 inches respectively, but the roof snow depth was 36 inches at the wall between the two roofs of elevations of 20 and 25 feet. Similar drifting patterns have also been observed around parapet walls.

A second type of drifting can occur due to aerodynamic shading of the leeward side of an arch or gabled roof. When a strong wind blows parallel to the ridge, it can remove some or most of the snow from the roof. However, if the wind blows perpendicular to the ridge, the windward side is unloaded, while additional load is placed on the leeward side. Examples of this type of drifting can be found in reference (11). This wind induced redistribution of roof snow was also noted by Lorenzen (7,8) in his investigation of the collapse of farm structures in upstate NY and also in the Canadian snow case history studies (9,15). This general effect is also taken into consideration by the Canadian (10) and ANSI (1) codes.

Structural Collapse Due to Snow

Over the years failure investigations and review of statistics on building collapse have proved quite useful to structural engineers. Herein, statistics on building collapse due to snow loads are reviewed. This review indicates the type of structures susceptable to collapse from snow, the type of loads causing collapse as well as estimates of the potential loss

due to snow load related collapse. Much of the information in this section comes from personal communications with individuals at Factory Mutual Insurance Company and Kemper Insurance Company. The information from Factory Mutual is quite useful in view of the fact that Factory Mutual insures approximately 60% of the industrial buildings in the United States.

The magnitude of the problem of structural collapse due to snow is illustrated by the fact that the 1977-78 winter resulted in more than two hundred building collapses with damage in excess of 40 million dollars. While a great many of these building collapses were due to the Blizzard experienced in the Northeastern United States that year, similar damage statistics are likely due to the heavy snow experienced in the Midwest during the 1978-79 winter. Information from both Factory Mutual and Kemper Insurance indicates that structural failure due to snow is about equal to structural failure due to pounding of rain both in terms of dollar loss and number of collapses.

The type of roof most likely to experience distress due to snow loads are metal deck roofs (18). For structures insured by Factory Mutual, approximately 60% of the failures are steel frame structures, 25% are wood joist while about 5% are bow string. Relatively few reinforced concrete structures failed due to snow. These statistics reflect the fact that structures with relatively high dead load to live load ratios generally do not collapse due to snow loads. Structural capacity due to safety factors on dead load can, if needed, resist excessive live load due to snow.

The majority of structural collapse due to snow occur at the lower level of multi level roofs (4,6). Loss naratives compiled by Kemper Insurance Company record one collapse due to snow on a flat roof and one collapse of a saw tooth roof. Most of the other Kemper loss naratives state

that the collapse occurred on a lower roof adjacent to a higher section. Statistics from Factory Mutual indicate that about 75% of their snow related collapses involve drifting on multi level roofs, 5% resulting from accumulation on one side of an arched roof, and the remainder involving relatively uniform loads on flat roofs.

Drifting on the lower portion of multi level roofs is usually caused by the wind blowing snow from the higher level roof to the adjacent lower portion. This corresponds to the case where the lower level roof is down stream or on the leeward side of the higher roof. Drifting can also occur on the lower roof which is upstream or on the windward side of the higher level roof. This drifting is caused by snow piling up against the wall of the higher building section. Although it has been observed, this loading mechanism is much less frequent.

Section 3

DATA ANALYSIS

DESCRIPTION OF COLLECTORS AND STRUCTURES

A total of eight structures were used to gather field data on snow and ice accumulation around solar collector installations. Three of the structures were located in New York State, three in New Hampshire and two in Connecticut. The wind exposure of each roof was classified by the data gatherer. Three of the installations were windswept, three were semi-sheltered and two were considered sheltered. All of the installations were essentially flat plate solar collectors located on the roof of the structure. For five of the structures, the collectors were between approximately 10 to 20 feet above the ground surface, while the remaining were at 35, 60 and 85 feet above the ground level. All of the collectors were at an angle between 45° and 60° with respect to a horizontal plane. Half of the collectors were flush with respect to their sloped roof surface, while the other half were at an angle with respect to their horizontal roof surfaces. The surface area of the collector installations varied from about 25 sq. ft. to 3000 sq. ft. More than half had surface areas in excess of 900 sq. ft. Two of the structures had essentially a single collector on the roof; one flush and the other at an angle to the roof surface. The others either had multiple rows of collectors at an angle to the roof or had a substantial portion of the roof surface covered with flush collectors. Plan and Elevation views of each individual structure are found in Appendix I. This information about the structures and the solar collectors is summarized in Table 1.

DATA GATHERING PROCEDURE

Each structure was visited at least once during the course of the research project. The visits were planned for after snowfalls when there was a reasonable probability that there would be snow on the roofs. If there was sufficient roof snow, at least two roof density samples and a ground density sample were taken during the visit. Sufficient roof and ground depth measurements were also taken to enable the data gatherer to draw contour lines for the roof snow and establish the average ground snow depth. The snow depth measurements were taken with a meter stick. Undisturbed snow cores of known volume, obtained using hollow 2½ inch diameter aluminum sampling tubes, were weighed to determine the snow density values. A more detailed description of the procedure for density samples is found in Appendix II.

Photographs of each solar collector installation were also taken during the visits. These photographs are found in Appendix III.

OWNERS COMMENTS

During the course of the data gathering visits, the owners or managers of the individual structures were interviewed to solicit their observations about snow and ice accumulation on and around their solar collector installations. These comments are presented in Table 2. In general, the comments indicate that there is no build up of snow on the solar collector themselves. The snow slides off the solar collectors shortly after the individual snow storms.

DATA REDUCTION

Snow and ice data sheets for the structures in this study are presented in Appendix IV. These data sheets were transcribed from rough data sheets

prepared for each structure during each visit. The data sheets record the date, air temperature, cloud cover, and precipitation, if any, during each visit. Also recorded are ground and roof sample densities, average ground snow depth, as well as depth contours of the roof snow. The measured maximum roof depth was also recorded along with the average roof depth for those areas covered by snow and the percentage of the roof covered by the snow. If a gabled roof had one side completely bare and a uniform four inches of snow on the other side, this would be recorded as 50% of the roof covered with an average of 4 inches. If on the other hand, a flat roof had a triangular distribution of snow, 0 depth at one edge and 12 inches depth at the other edge, the average depth would be recorded as six inches, while the percentage of roof covered would be 100%.

The information in Appendix III is summarized in Table 3. In Table 3 the average roof snow density for each building visited is listed as opposed to the individual sample densities. These values can be used to calculate the average ground load P_g as well as the average P_{ar} and peak P_{pr} roof loads. The units for the ground and roof loads are lbs. per sq. ft. and are calculated

$$P_g = h_g \gamma_g/12 \tag{1}$$

$$P_{ar} = h_{ar} \gamma_r A_r/12 \tag{2}$$

$$P_{pr} = h_{pr} \gamma_r/12 \tag{3}$$

Where h_g, h_{ar} and h_{pr} are the average ground, average roof and peak roof depths; γ_g and γ_r are the average ground and roof densities and A_r is the percentage of roof covered by snow. Because of the definitions of h_{ar} and A_r discussed previously, P_{ar} corresponds to the total weight of roof snow

divided by the plan area of the roof. P_{pr}, on the other hand, is the maximum intensity of the snow load on the roof.

The average ground and roof loads as well as the peak roof loads for each visit are listed in Table 4. As one might expect, the ground snow loads for the two structures in Connecticut (Lutz Sotire and Albie Booth) are the lowest while the ground loads for the three structures in New Hampshire (Contemporary Systems, Alderman, and Norris-Cotton) are the highest. The average roof loads are much more variable and will be discussed in more detail later. The peak roof load in one case was more than 6 times the average ground load value while in four other cases the peak roof load was about twice the ground load. It should be noted, that the peak load generally effects only a small portion of the roof surface.

The final step in the data reduction process involves calculating ground and roof conversion factors. The average design conversion factor C_{fa} for a particular structure during a given winter is the maximum average roof load during the winter $(P_{ar})_{max}$ divided by the maximum ground load $(P_g)_{max}$ during the winter, that is

$$C_{fa} = (P_{ar})_{max}/(P_g)_{max} \tag{4}$$

where

$$(P_{ar})_{max} = \max_{i = 1,..n} (P_{ar})_i \tag{5}$$

and

$$(P_g)_{max} = \max_{i = 1,..n} (P_g)_i \tag{6}$$

Note that the maximum average roof load may occur on a different day than the maximum ground load as, for instance, was the case for the Alderman

residence. Since the average design conversion factor is a ratio of yearly maximum, there is only one value for this ratio per year per structure.

Another conversion factor of interest is the design conversion factor for peak roof loads C_{fp} defined as

$$C_{fp} = (P_{pr})_{max}/(P_g)_{max} \tag{7}$$

where

$$(P_{pr})_{max} = \max_{i=1,..n} (P_{pr})_i \tag{8}$$

As with the average design conversion factor there is only one value for the peak design conversion factor per structure per year. The average and peak design conversion factors for the structures in the study along with the structure's wind exposure rating and roof slope are presented in Table 5.

Analysis of Results

The easiest results to analysis are those dealing with snowloads on the collectors themselves. For thirteen of the fourteen data gathering visits, there was no snow on the solar collectors as recorded on the snow and ice data sheets. Particularly interesting is the data sheet for the February 16 visit to Contemporary Systems. The average ground and roof depths were 12 and 11 inches respectively, yet the solar collector itself is free of snow. The snow slid off the solar collector which is at an angle of 60 degrees with respect to the horizontal plane and formed a mound 19 to 22 inches in depth near the base of the collector. A review of other snow and ice data sheets as well as the owners comments, indicates that this is typical. This is due, no doubt, to the relatively steep angle,

between 45 and 60 degrees, at which solar collectors are oriented in the northern portions of the United States as well as the relatively slippery glass surface of the collectors themselves.

A review of the material presented in Table 5, shows the influence of roof slope and wind exposure upon the average design conversion factor. For three of the eight structures studied (SUNYA, Shook, and Alderman) the major portion of the roof had slopes between 30 and 50 degrees. The average design conversion factor for the Alderman residence was 0.04 while C_{fa} for the other two could not be calculated because there was insufficient roof snow for density measurements. Three of the remaining five structures (Norris Cotton, Lutz Sotire, and Albie Booth) were flat and had C_{fa} values ranging from 0.12 to 0.82. The remaining two structures (Cary, and Contemporary Systems) had portions of their roofs at 35 degrees and the remaining portions flat. For these two structures the C_{fa} values range from .39 to 0.27.

This data indicates that roof slopes greater than 30 degrees can have a significant effect upon the average design conversion factor. Similar conclusions about the effect of roof slope had been made for structures without solar collector installations.

The next major parameter to be analyzed is the structure's wind exposure. For this analysis, the three structures where the roof slope appeared to be the major factor (SUNYA, Shook, and Alderman) will be eliminated. That is, only structures which have relatively flat roofs or which have a substantial flat portion are analyzed to determine the effect of wind exposure. Three of these structures were originally classified as wind swept by the data gather, one classified as semi-sheltered and one sheltered. This original classification was based upon the elevation and location of the roof with

respect to trees and other wind breaks. However upon review of the snow and ice data sheets, it appears that the Lutz Sotire building should be reclassified from wind swept to semi-sheltered because of the presence of solar collectors on the roof. There is a bare spot near the southern edge of the structure which indicates that the wind blew out at the south, perpendicular to the orientation of the collectors. Slightly north of the bare spot on Lutz Sotire, the solar collectors and reflectors, the bottom of which were located about 15 inches from the flat roof surface, appeared to have acted as a snow fence. Except for mounds due to snow sliding off collectors, the snow is fairly uniform with a depth varing between 5 and 7 inches. Since the solar collector on Lutz Sotire seems to have acted as a snow fence, it seems reasonable to reclassify the structure from wind swept to semi-sheltered. Note that solar collectors tend to act as a snow fence only if they are at an angle with respect to the roof surface, are oriented perpendicular to the prevailing wind direction, and are located close to the roof surface.

A question now arises as to reclassification of the other structures with solar collectors at an angle with respect to the roof surface. Since the Contemporary Systems roof was initially classified as sheltered, the snow fence concept is not applicable and reclassification is not justified. The solar collectors on the Norris Cotton building are on the southern portion of the roof and three out of the four collector banks are more than 7 feet from the primary roof surface. Since the wind appears to have blown out of the north, the snow fence effect is also minimal for Norris Cotton and again reclassification is not justified. From the snow and ice data sheets for Albie Booth, it appears that the wind comes from the east or east

southeast. Since the solar collectors for Albie Booth are oriented parallel to this assumed wind direction, they are not effective as a snow fence.

Presented in Table 6 are the average design conversion factors for the five structures with flat or predominately flat roofs, grouped according to wind exposure. Note, in this table the Lutz Sotire structure is considered semi-sheltered because of the snow fence effect. The effect of wind exposure upon the average design conversion factor is readily evident in Table 6. The sheltered structure has a considerably higher average design conversion factor and the wind swept structures have considerably lower design conversion factors. These average design conversion factors are not substantially different from those determined by the author (14) for structures without solar collector installations on the roof.

For structures without solar collector installations, the peak load and the peak design conversion factor is usually associated with wind drifted snow. As mentioned previously, the drift can be due to the presence of parapets, areodynamic shading of a portion of the roof, or roofs at different elevations. Some of the sources of drifts and peak loads are illustrated by the snow and ice data sheets. For example, drifting caused by the presence of parapet walls is illustrated by the data sheets for Albie Booth on February 21. There is however, an additional mechanism causing peak loads for structures with the solar collectors on their roofs. This mechanism is one in which snow slides off the solar collectors and piles up on the roof surface near the base of the collector. While the driving force behind the other mechanisms is the wind, gravity is the driving force for this mechanism. This means that drifting by this mechanism is possible in a relatively sheltered environment such as was illustrated by the data sheet for Comtemporary Systems on February 16.

The peak design conversion factor was due to snow sliding off the solar collector for three of the eight structures in this study. For these three structures, Lutz Sotire, Contemporary Systems and Cary, the C_{fp} values presented in Table 5 are all surprisingly close to 2.0. It should be noted that the sliding mechanism can not lead to drifting and peak loads for some structures with solar collectors flush with respect to the roof surface. For example, the snow sliding off of the collectors on the Alderman residence fall to the ground as opposed to the roof surface.

Roof thermal characteristics and the type of winter are two other parameters which effect ground to roof conversion factors. However, because of the relatively small number of structures in this study, it is difficult to investigate these effects with the data gathered during this study.

Section 4

SUMMARY AND SUGGESTIONS FOR FURTHER RESEARCH

In this section, the research results pertaining to snow loads around solar collector installations are summarized. It is very important to note that the results presented herein are based upon a very small number of structures, studied over only part of one winter. Because of this, trends as opposed to specific values or ratios are emphasized. Before specific values can be recommended, more snow load field data must be obtained. In addition, other suggestions for further research, which is necessary before firm design guidelines can be established, are also presented in this section

Owner's comments, as well as the snow and ice data sheets, indicate that snow slides off the solar collectors shortly after the end of a snow storm. Because there tends to be little or no accumulation on the collectors from storm to storm, it seems reasonable to use the water equivalent to a single snowfall with a sufficiently larger return period as a design load for the solar collectors themselves as opposed to a conversion factor times a maximum accumulated ground load. Hence, extreme value distribution studies of the water equivalent of individual snowfalls should be undertaken.

The average design conversion factor for roofs with solar collectors at an angle with respect to the roof surface tends to be similar to C_{fa} values for structures without collectors except for what has been referred to as the snow fence effect. If the solar collectors are at an angle with respect to the roof surface, oriented perpendicular to the predominant wind direction (wind from the north or south for solar collectors which face south) and located close to the roof surface, they can shelter the roof snow from wind. As illustrated by this study, this can result in higher roof loads than would

normally be expected for the same structure without the solar collectors. Further study is needed to quantify this effect in terms of geometric and wind parameters such as wind speed and direction, number of collector banks, distance between bottom of collector and roof surface, etc. Controlled prototype and/or model studies could prove quite useful in this regard.

The peak depth as opposed to the average depth of roof snow has also been shown to be effected by solar collectors on the roof. Snow which slides off the solar collector surface can pile up at its base and form a drift. For example, a flat roof adjacent to the southern edge of the SUNYA Alumni Center would, if present, have received a substantial load due to the four rows of collectors running along the roof. From a structural engineering view point, the importance of this or other types of drifts is a function of the structural layout of the roof. If the roof joists run parallel to the drift, one or two roof joist may be required to support the whole drift. If, on the other hand, the roof joist run perpendicular to the drift, the situation is not as critical since many joist are available to support the drift. There are many questions which are yet to be answered about this particular drifting mechanism. Because of insufficient data, the interrelationships between the peak design conversion factor on the one hand, and the thermal characteristics, geometric and wind environment of the roof, on the other hand, are unknown at the present time.

References

1. American National Standards Building Code Requirements for Minimum Design Loads in Building and Other Structures (ANSI A58.1-1972), American National Standard Institute, New York, 1972.

2. Anderson, A., "Snow Loads For Roofs", Civil Engineering, July 1965, p. 76.

3. Boyd, D., "Maximum Snow Depths and Snow Loads on Roofs in Canada", Proc. Western Snow Conference, Spokane, Washington, April 1961.

4. Burke, M.F., Private communication, Nov. 1978.

5. Ghiocel, D. and Lungu, D., "Wind, Snow and Temperature Effects on Structures Based on Probability", Abacus Press, Kent, England, 1975.

6. Hassell, V.J., Private communication, Dec. 1978.

7. Lorenzen, R., "Observations of Snow and Wind Loads Precipitant to Building Failures in New York State 1969-70", Paper No. 70-305, American Society Agricultural Engr., North Atlantic Meeting, Newark, Del., Aug. 1970.

8. Lorenzen, R., "Modes of Structural Failure At Critical Snow Load", Paper No. 70-920, American Society Agricultural Engr. Winter Meeting, Chicago, Ill., Dec. 1970.

9. Lutes, D. and Schriever, W., "Snow Accumulation in Canada, Case Histories II", Tech. paper 339, Division of Building Research, National Research Council, Ottawa Canada, March 1971.

10. National Building Code of Canada, National Research Council, Canada #11530, Ottawa, 1970.

11. O'Rourke, M., "Snow Load Data Analysis", report prepared for U.S. Army Cold Regions Research and Engr. Lab., Hanover, N.H., June 1976.

12. O'Rourke, M., "Snow Load Data Analysis - Winter of 1976-77", report prepared for U.S. Army Cold Regions Research and Engr. Lab., Hanover, N.H., July 1977.

13. O'Rourke, M.J., "Snow Loads on Structures", Proceedings of Cold Regions Specialty Conference, ASCE, Anchorage, Alaska, May 1978, 11p.

14. O'Rourke, M.J., "Snow Load Data Analysis - Winter 1977-78", Report prepared for the U.S. Army Cold Regions Research and Engr. Lab., Hanover, N.H., July 1978, 26p.

15. Schriever, W., Faucher, Y., and Lutes, D., "Snow Accumulation in Canada Case Histories I", Tech. paper 237, Div. of Building Research, National Research Council, Ottawa, Canada, Jan. 1967.

16. Thom, H.C.S., "Distribution of Maximum Annual Water Equivalent Snow on the Ground", Monthly Weather Review, Vol. 94, No. 4, April 1966, p. 265-271.

17. Tobiasson, W. and Redfield, R., "Alaskan Snow Loads", 24th Alaskan Science Conf., Univ. of Alaska, Aug. 1973.

18. Tucker, D.B., "Preventing Roof Collapse from Snow Overload", The Sentinel, Industrial Risk Insurers, Nov.-Dec. 1978, p. 11-14.

Name	Location	Wind Exposure of Roof	Approx. Height of Collectors Above Ground (ft.)	Angle Between Collector and Horizontal Plane (deg.)	Orientation of Collector With Respect to Roof Surface	Approx. surface area of Collectors (ft^2)
SUNYA Alumni Center	Albany N.Y.	Semi-Sheltered	18	50	Flush	900
Cary Arboretum	Millbrook N.Y.	Semi-Sheltered	10	60	Flush	3000
Shook Residence	Scotia N.Y.	Sheltered	22	45	Flush	25
Contemporary Systems Bldg.	Jaffery N.H.	Sheltered	18	60	At Angle	90
Alderman Residence	Jaffrey N.H.	Semi-Sheltered	12	45	Flush	180
Norris Cotton Bldg.	Manchester N.H.	Windswept	85	45	At Angle	2900
Lutz Sotire Bldg.	Stamford Conn.	Windswept	60	55	At Angle	1800
Albie Booth Boys Club	New Haven Conn.	Windswept	35	55	At Angle	2000

Table 1. Description of Solar Collectors and Structures Studied

STRUCTURE	COMMENTS
SUNYA ALUMNI CENTER	No problem with buildup, wet snow sticks but slides off shortly after. Deep piles of snow build up on ground below collector.
CARY ARBORETUM	Snow slides off collectors shortly after storm. No problem with snow buildup at base of collectors.
SHOOK RESIDENCE	No problem with snow buildup on collector. Snow sticks until sun comes out or temperature warms up
CONTEMPORARY SYSTEMS	No problems with buildup of snow on collectors
ALDERMAN RESIDENCE	No problems with buildup. Snow slides off shortly after storm.
LUTZ-SOTIRE BUILDING	No snow buildup on collectors. Snow does collect on reflectors although it slides off with sun or warming temperatures.
ALBIE BOOTH BOYS CLUB	No problems with builup although collectors are not yet in operation.

Table 2. Owners Comments on Snow and Ice Accumulation On and Around Solar Collector Installations.

Structure	Date of Visit	Average Ground Depth h_g (in.)	Average Roof Depth h_{ar} (in.)	Peak Roof Depth h_{pr} (in.)	Average Ground Density γ_g (pcf)	Average Roof Density γ_r (pcf)	Percentage Roof Covered A_r (%)
SUNYA	2/9/79	6	3	4	21.1	+	15
"	2/28/79	5	2	5	25.6	+	15
CARY	2/9/79	3.5	3	9	6.0	10.5	60
"	2/28/79	2	1	3	26.3	34.0	60
SHOOK	2/9/79	8.5	1.5	3	20.3	+	30
"	2/28/79	12	2	5	24.3	+	10
CONT. SYS.	2/16/79	12	11	22	20.5	21.8	100
"	3/9/79	7	0	0	27.5	0.0	0
ALDERMAN	2/16/79	16	4	8	18.7	14.5	40
"	3/9/79	18	0	0	31.7	0.0	0
NORRIS-COTTON	2/16/79	5	3	15	22.1	17.7	25
"	4/9/79	1.5	1.5	8	+	+	95
LUTZ-SOTIRE	2/21/79	5.5	5	10	12.3	14	80
ALBIE BOOTH	2/21/79	3	5	20	15.5	15.3	20

+ Insufficient snow for density measurements

Table 3. Summary of Snow and Ice Data Sheets

Structure	Date	Average Ground Load P_g (#/□')	Average Roof Load P_r (#/□')	Peak Roof Load P_{pr} (#/□')
SUNYA	2/9/79	10.6	+	+
"	2/28/79	10.7	+	+
CARY	2/9/79	1.75	1.57	7.88
"	2/28/79	4.38	1.71	8.50
SHOOK	2/9/79	14.4	+	+
"	2/28/79	24.3	+	+
CONT. SYS.	2/16/79	20.5	19.9	39.9
"	3/9/79	16.0	0.00	0.00
ALDERMAN	2/16/79	24.9	1.99	9.70
"	3/9/79	47.5	0.00	0.00
NORRIS-COTTON	2/16/79	9.21	1.10	22.1
"	4/9/79	+	+	+
LUTZ-SOTIRE	2/21/79	5.73	4.75	11.9
ALBIE-BOOTH	2/21/79	3.87	1.28	25.5

+ Insufficient snow for density measurements

Table 4. Average Ground Loads, Average Roof Loads and Peak Roof Loads

Structure	Wind Exposure	Roof Slopes (excluding collectors)	Average Design Conversion Factor C_{fa}	Peak Design Conversion Factor C_{fp}
SUNYA	Semi-sheltered	50°,20°	+	+
CARY	Semi-sheltered	35°, 0°	.39	1.94
SHOOK	Sheltered	45°	+	+
CONT. SYS.	Sheltered	35°, 0°	0.97	1.97
ALDERMAN	Semi-sheltered	30°, 45°	0.04	0.20
NORRIS-COTTON	Windswept	0°	0.12	2.40
LUTZ-SOTIRE	Windswept	0°	0.83	2.07
ALBIE BOOTH	Windswept	0°	0.33	6.58

+ Insufficient roof snow for density measurement

Table 5. Average and Peak Design Conversion Factors, Wind Exposure and Roof Slope

Wind Exposure Rating	Structure	Average Design Conversion Factor C_{fa}	Mean C_{fa}
Windswept	Albie Booth, Norris-Cotton	0.33, 0.12	0.22
Semi-Sheltered	Lutz-Sotire, Cary	0.83, 0.39	0.61
Sheltered	Contemporary Systems	0.97	0.97

Table 6. Effect of Wind Exposure Upon Average Design Conversion Factor

Appendix I

Plan and Elevation Views of Structures

BUILDING: SUNYA ALUMNI CENTER

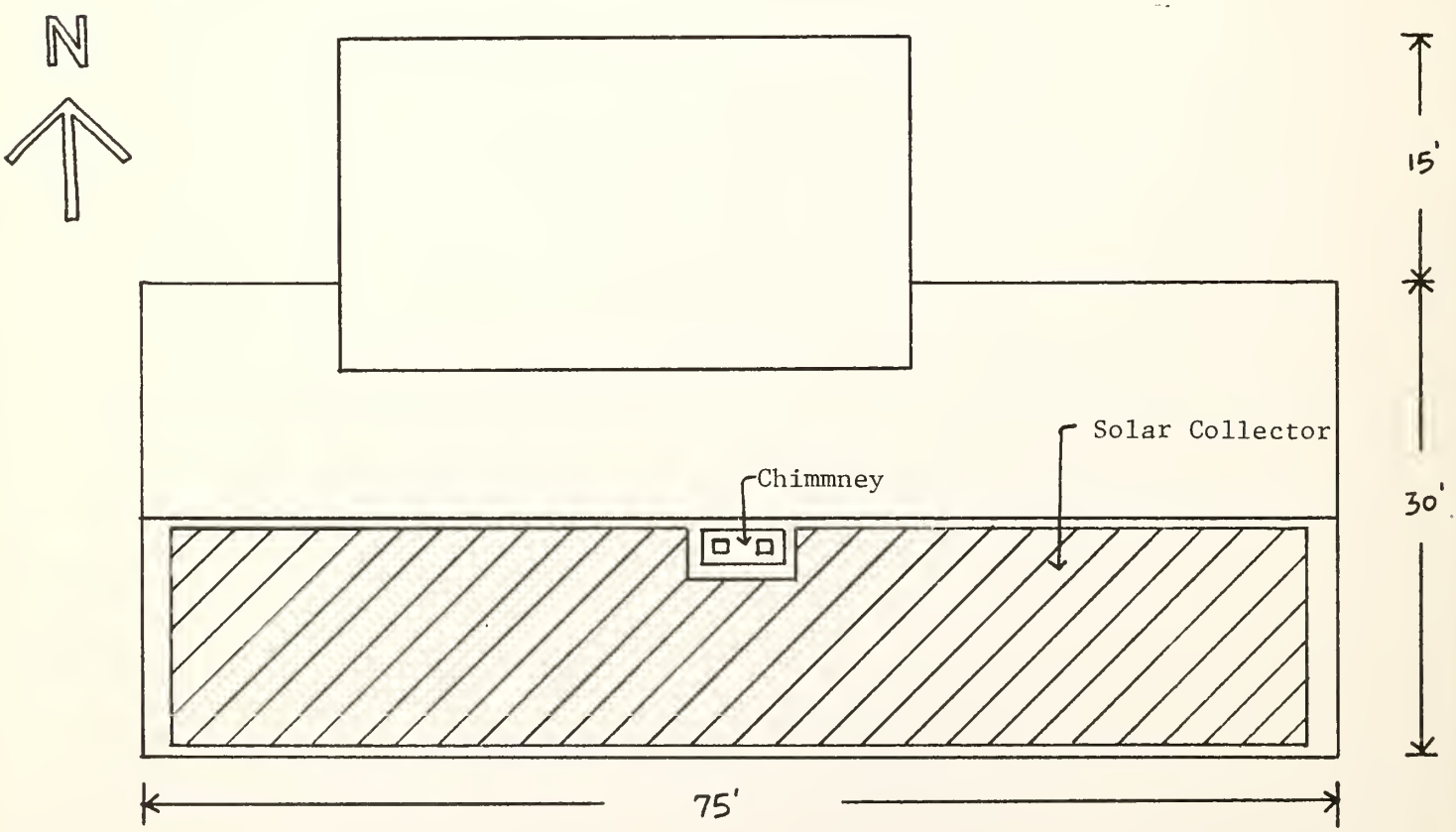
WIND EXPOSURE: SEMI-SHELTERED

LOCATION: ALBANY, N.Y.

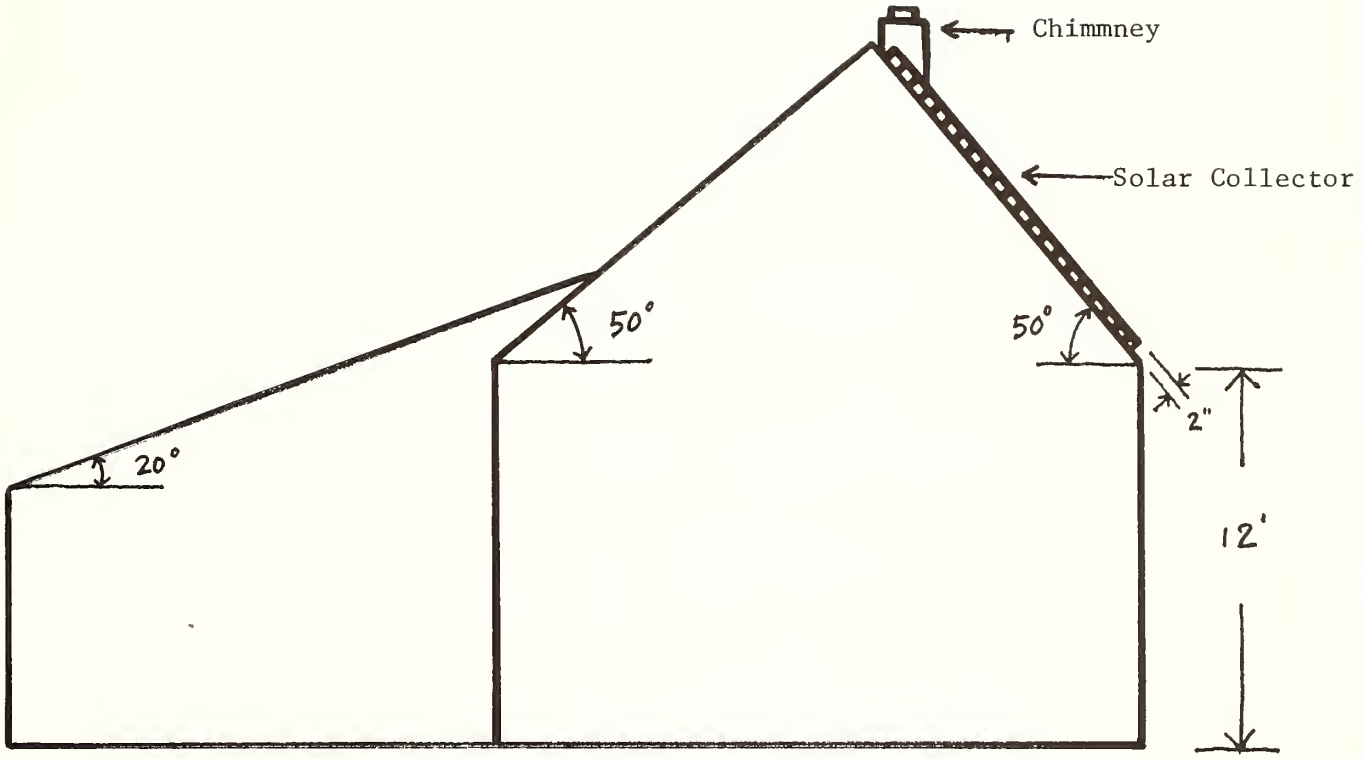
BUILDING HEATED: YES

ROOFING MATERIAL: SHINGLES

SOLAR COLLECTOR ORIENTATION: FLUSH



PLAN VIEW - SUNYA ALUMNI CENTER



ELEVATION VIEW - SUNYA ALUMNI CENTER

BUILDING: CARY ARBORETUM

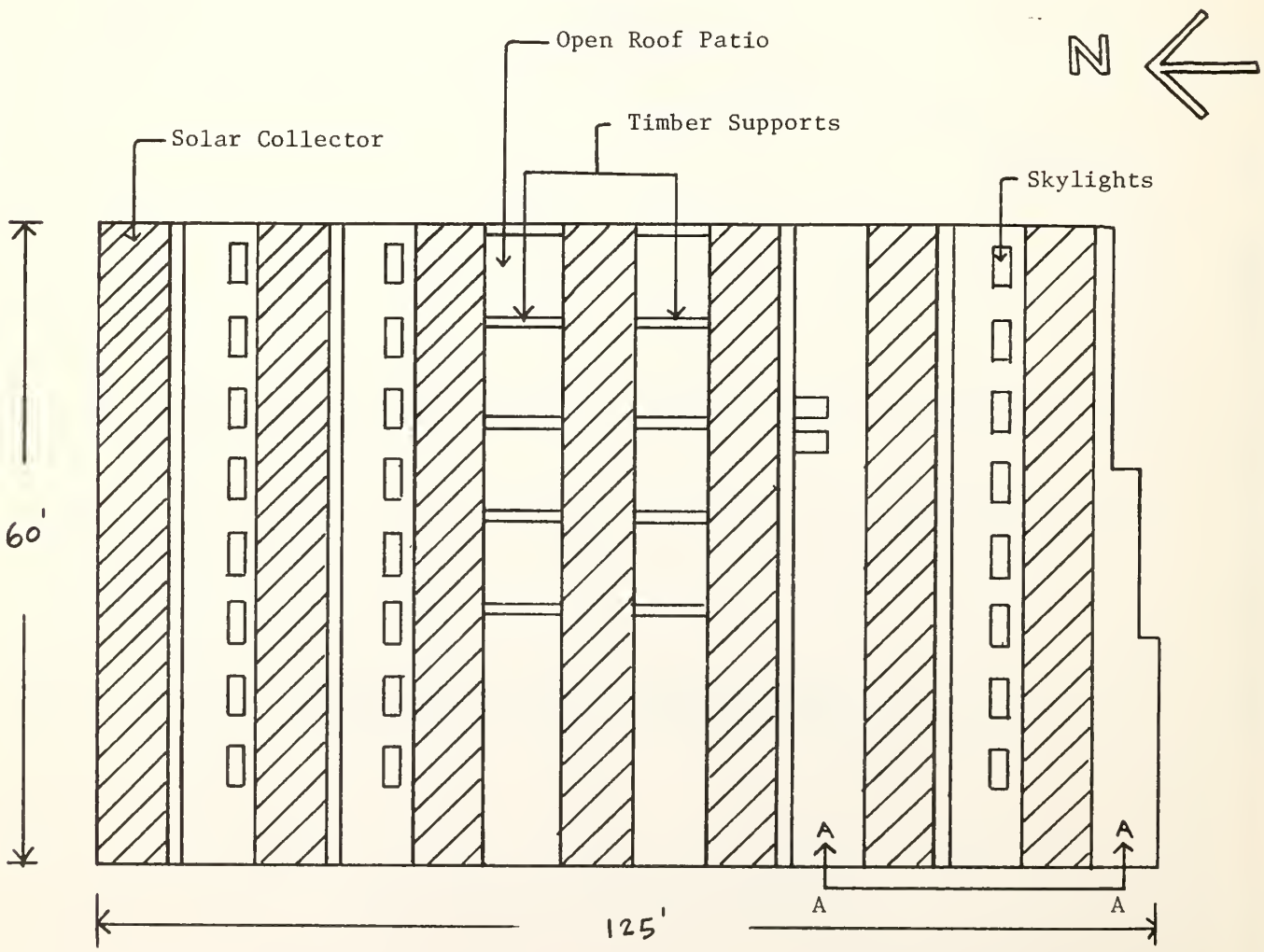
WIND EXPOSURE: SEMI-SHELTERED

LOCATION: MILLBROOK, N.Y.

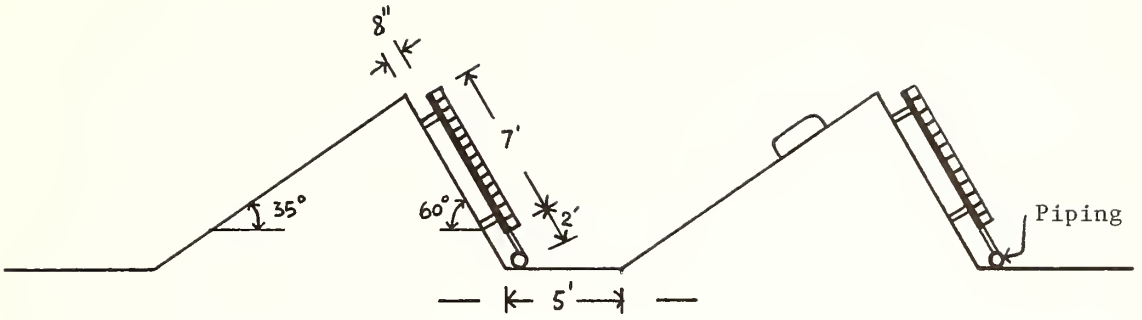
BUILDING HEATED: YES

ROOFING MATERIAL: SHINGLES

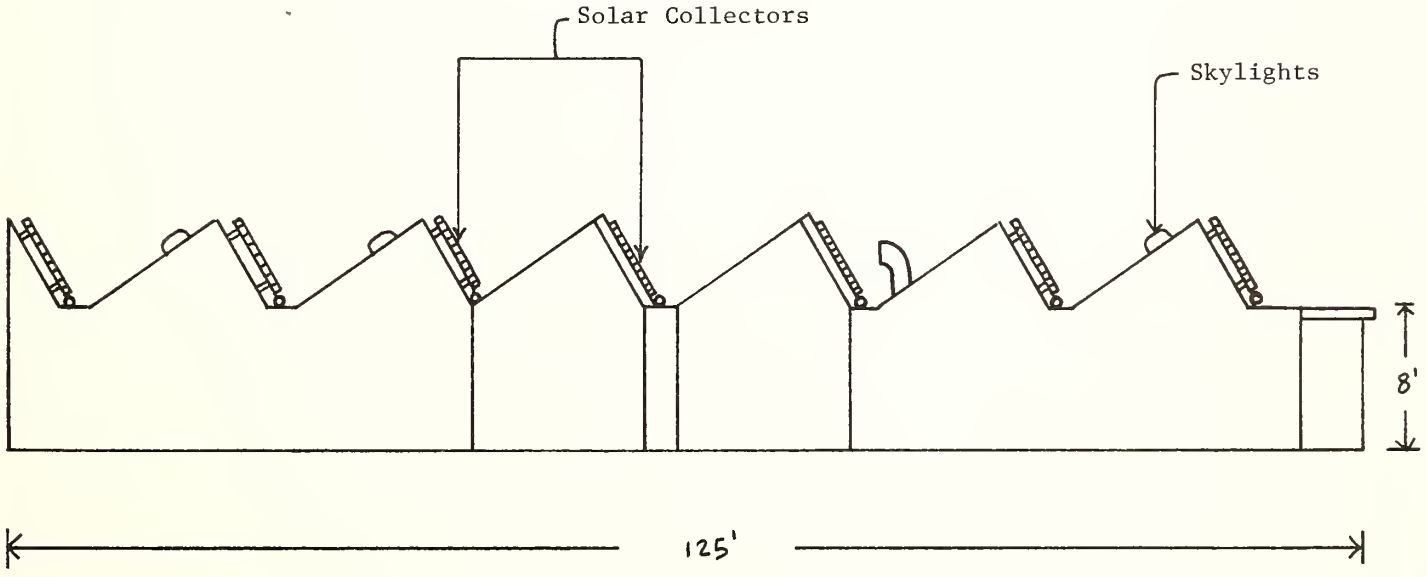
SOLAR COLLECTOR ORIENTATION: FLUSH



PLAN VIEW - CARY ARBORETUM



SECTION A-A EDGE VIEW OF SOLAR COLLECTORS



ELEVATION VIEW - CARY ARBORTEUM

BUILDING: SHOOK RESIDENCE

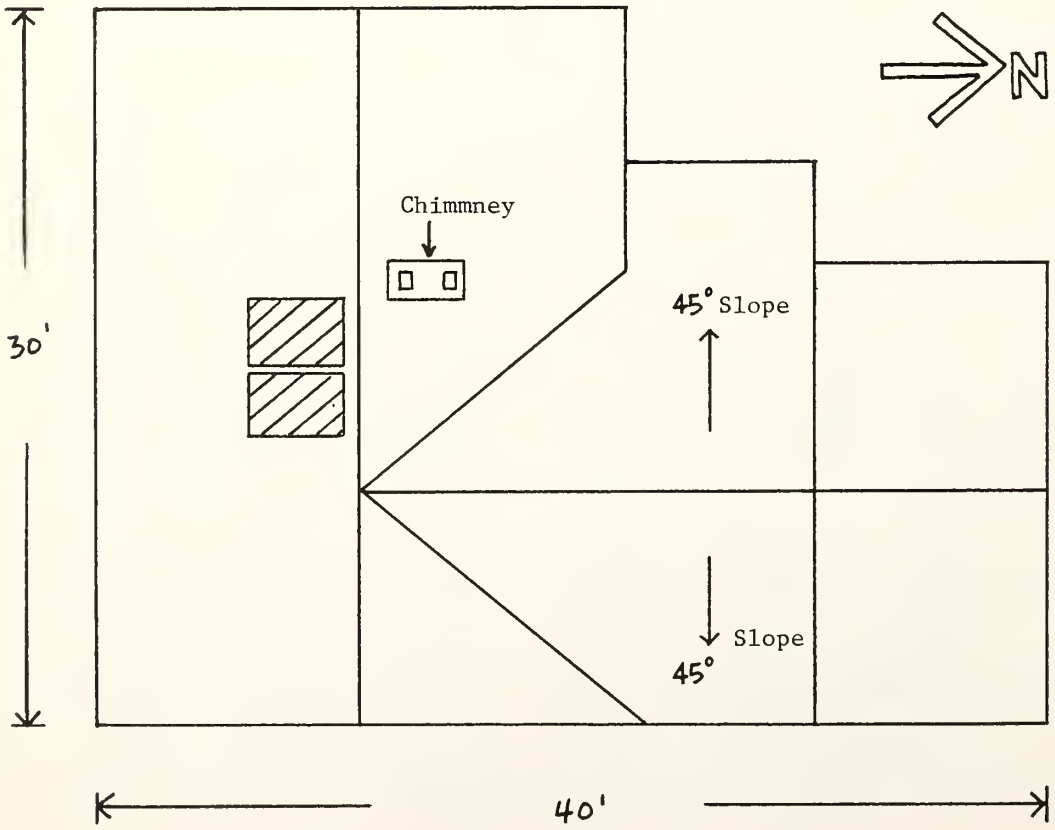
WIND EXPOSURE: SHELTERED

LOCATION: SCOTIA, N.Y.

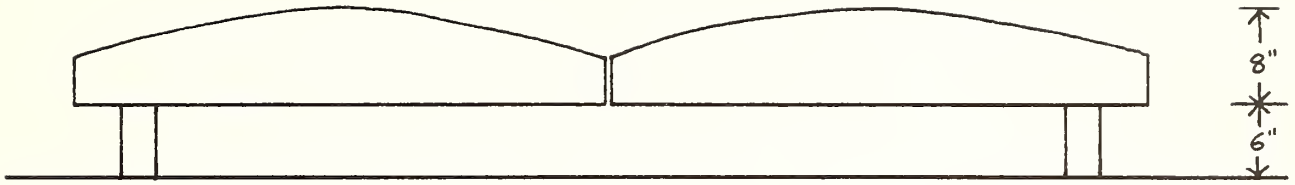
BUILDING HEATED: YES

ROOFING MATERIAL: SHINGLES

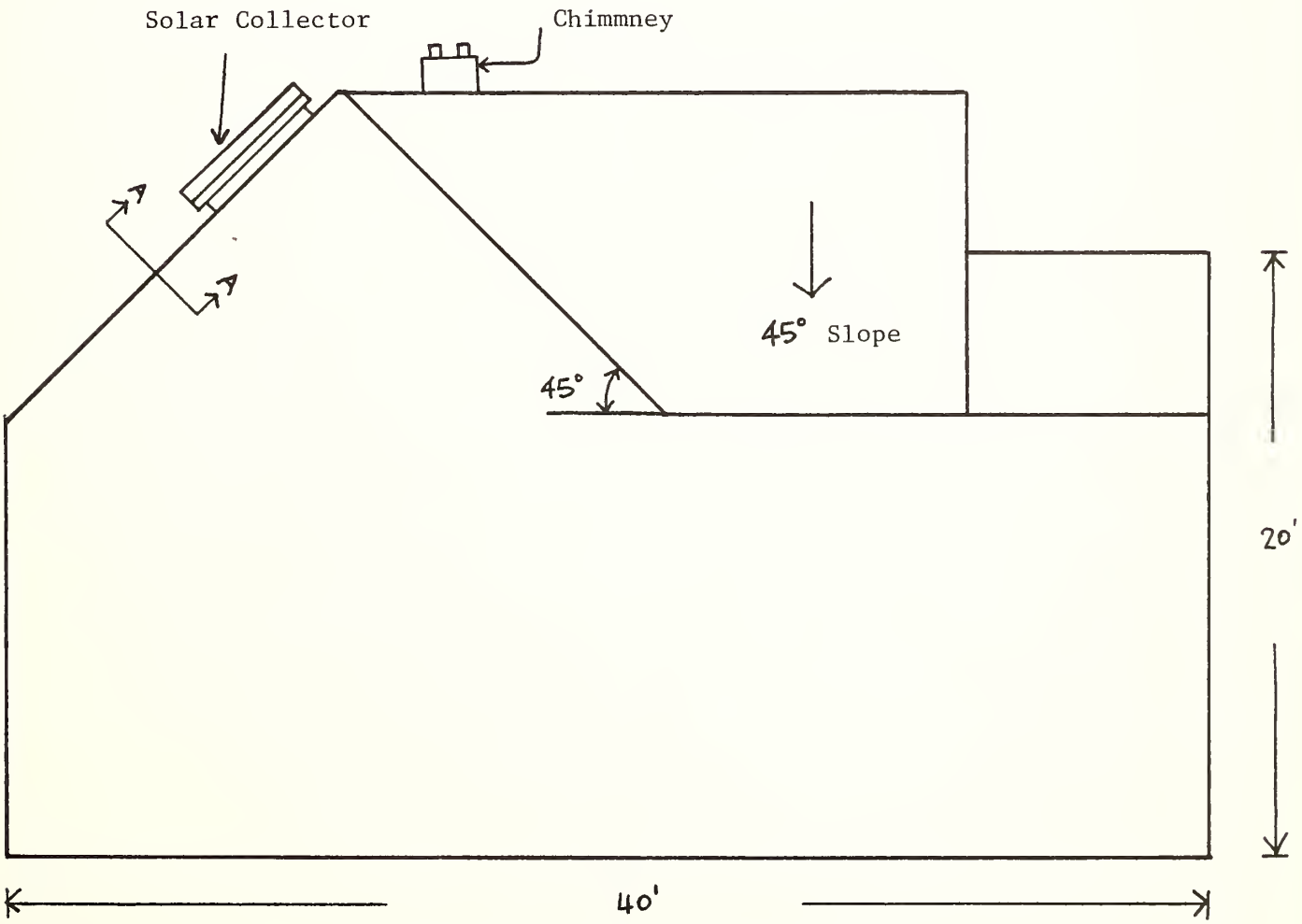
SOLOR COLLECTOR ORIENTATION: FLUSH



PLAN VIEW - SHOOK RESIDENCE



SECTION A-A EDGE VIEW OF SOLAR COLLECTOR



ELEVATION VIEW - SHOOK RESIDENCE

BUILDING: CONTEMPORARY SYSTEMS

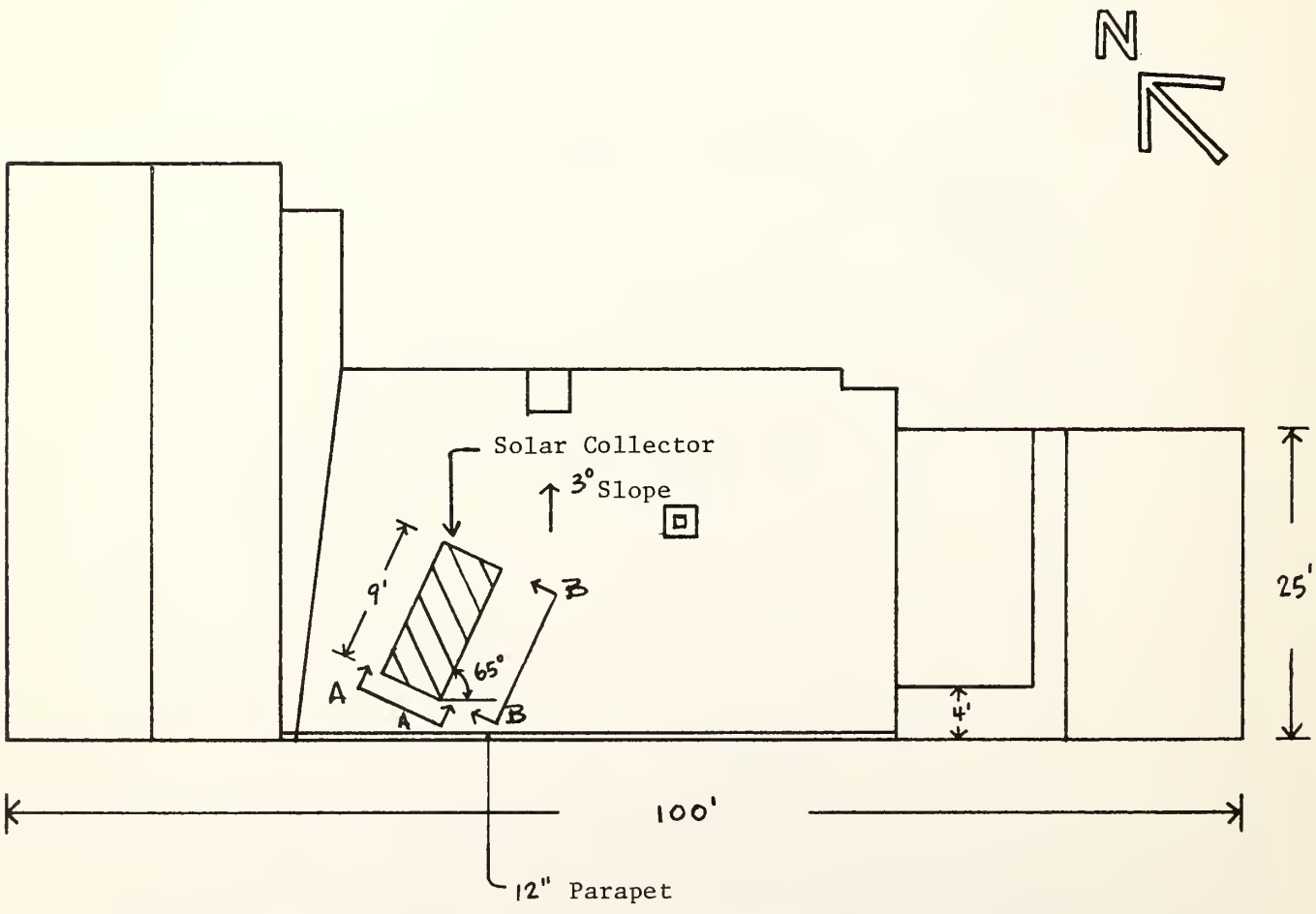
WIND EXPOSURE: SHELTERED

LOCATION: JAFFREY, N.H.

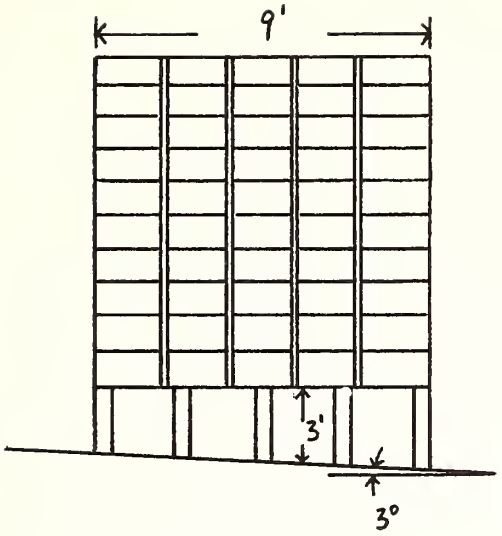
BUILDING HEATED: YES

ROOFING MATERIAL: TAR

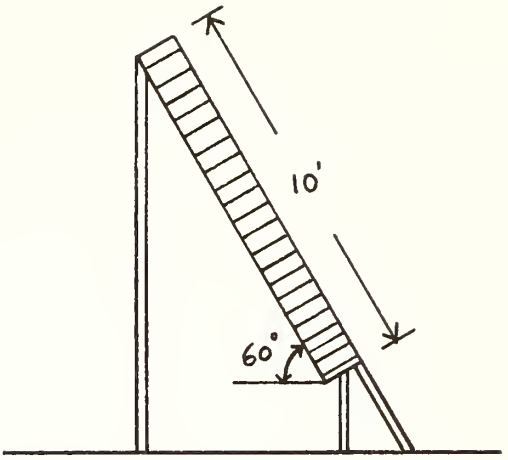
SOLAR COLLECTOR ORIENTATION: FLUSH



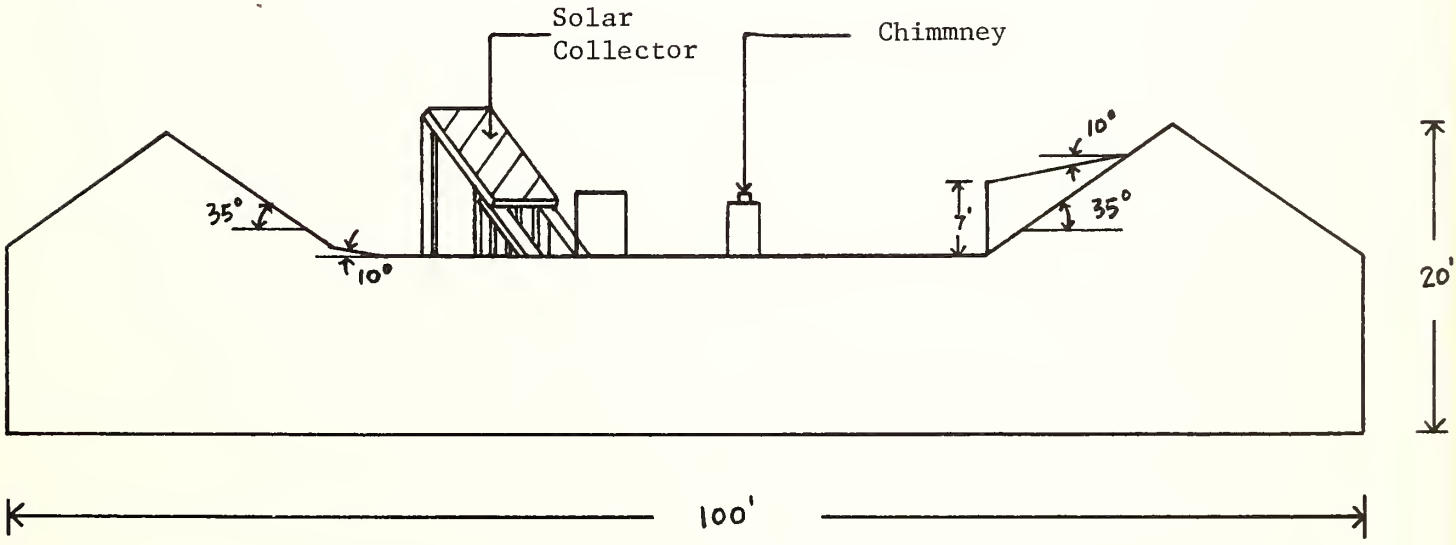
PLAN VIEW - CONTEMPORARY SYSTEMS



SECTION B-B FRONT VIEW



SECTION A-A EDGE VIEW



ELEVATION VIEW - CONTEMPORARY SYSTEMS

BUILDING: ALDERMAN RESIDENCE

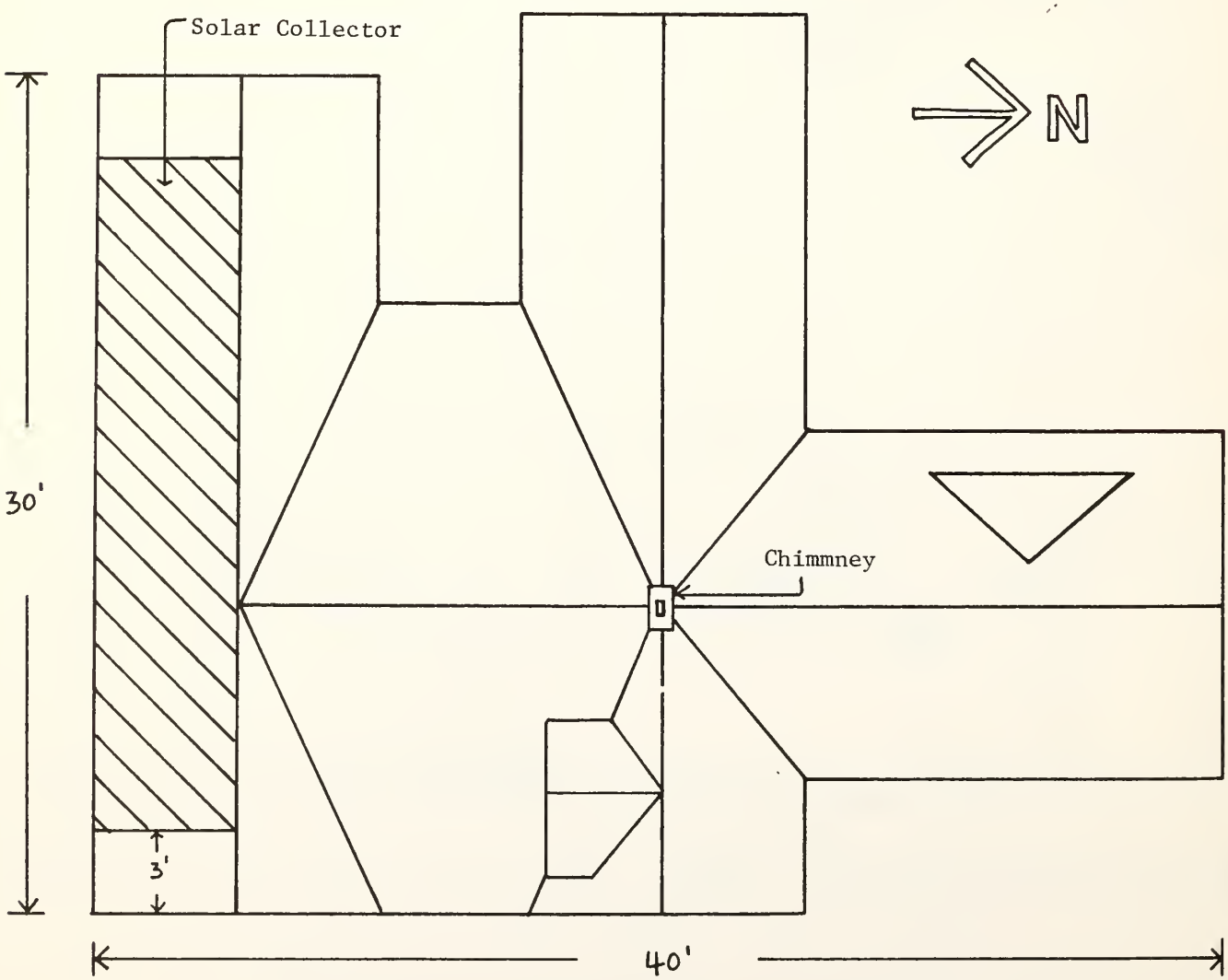
WIND EXPOSURE: SEMI-SHELTERED

LOCATION: JAFFREY, N.H.

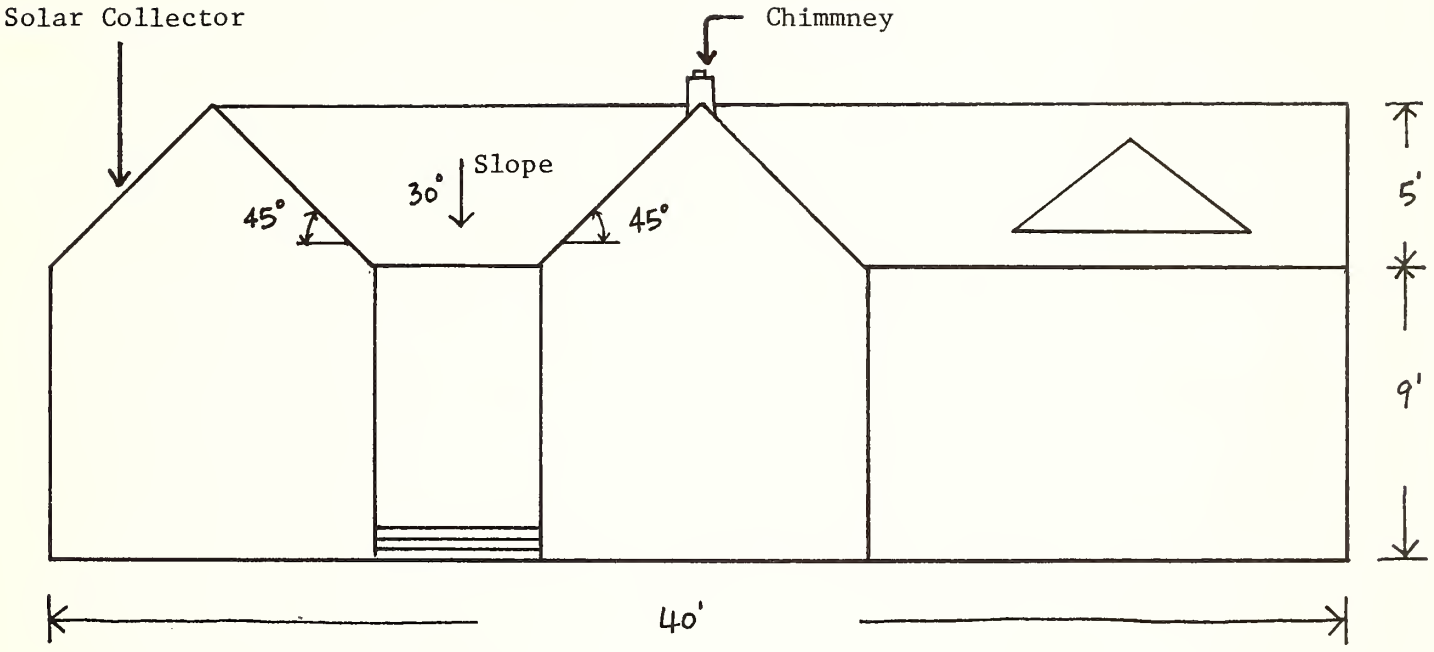
BUILDING HEATED: YES

ROOFING MATERIAL: SHINGLES

SOLAR COLLECTOR ORIENTATION: FLUSH



PLAN VIEW - ALDERMAN RESIDENCE



ELEVATION VIEW - ALDERMAN RESIDENCE

BUILDING: NORRIS COTTON BUILDING

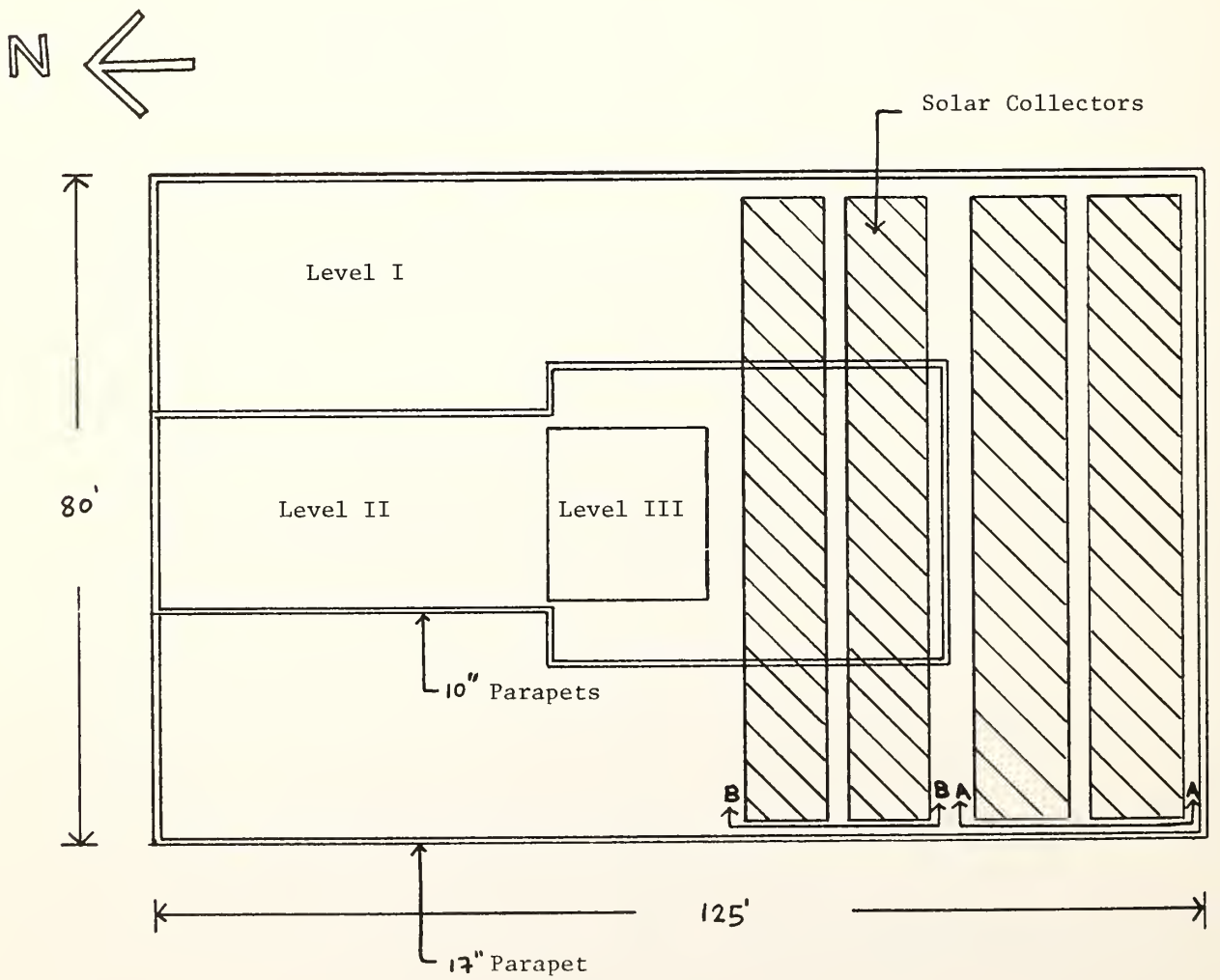
LOCATION: MANCHESTER, N.H.

ROOFING MATERIAL: GRAVEL

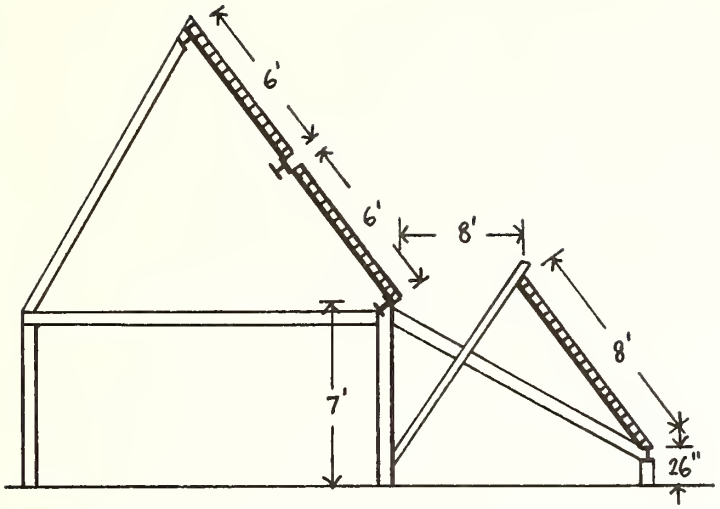
WIND EXPOSURE: WINDSWEPT

BUILDING HEATED: YES

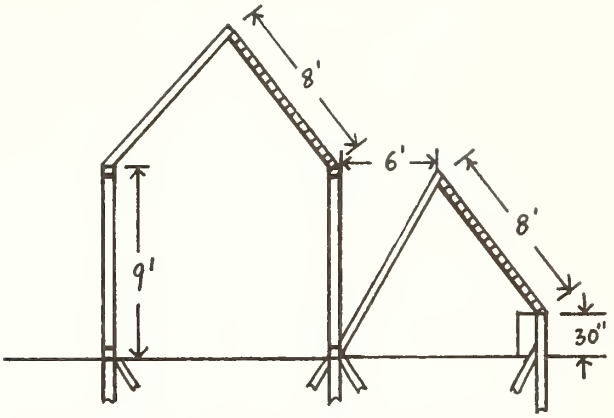
SOLOR COLLECTOR ORIENTATION: AT ANGLE W.R.T. ROOF



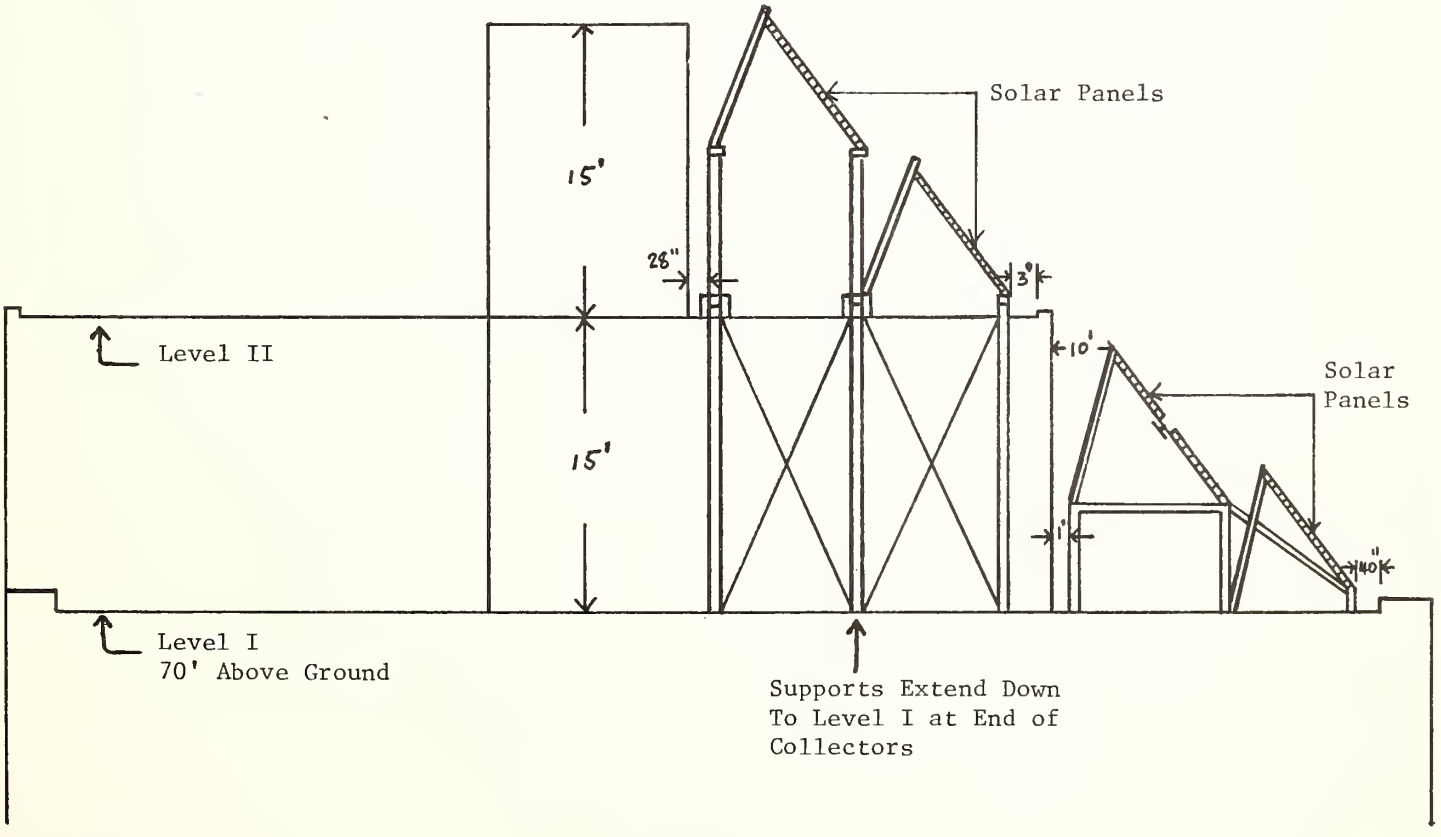
PLAN VIEW - NORRIS COTTON BUILDING



SECTION A-A EDGE VIEW OF COLLECTORS ON LEVEL I



SECTION B-B EDGE VIEW OF COLLECTORS ON LEVEL II



ELEVATION VIEW - NORRIS COTTON BUILDING

BUILDING: LUTZ-SOTIRE BUILDING

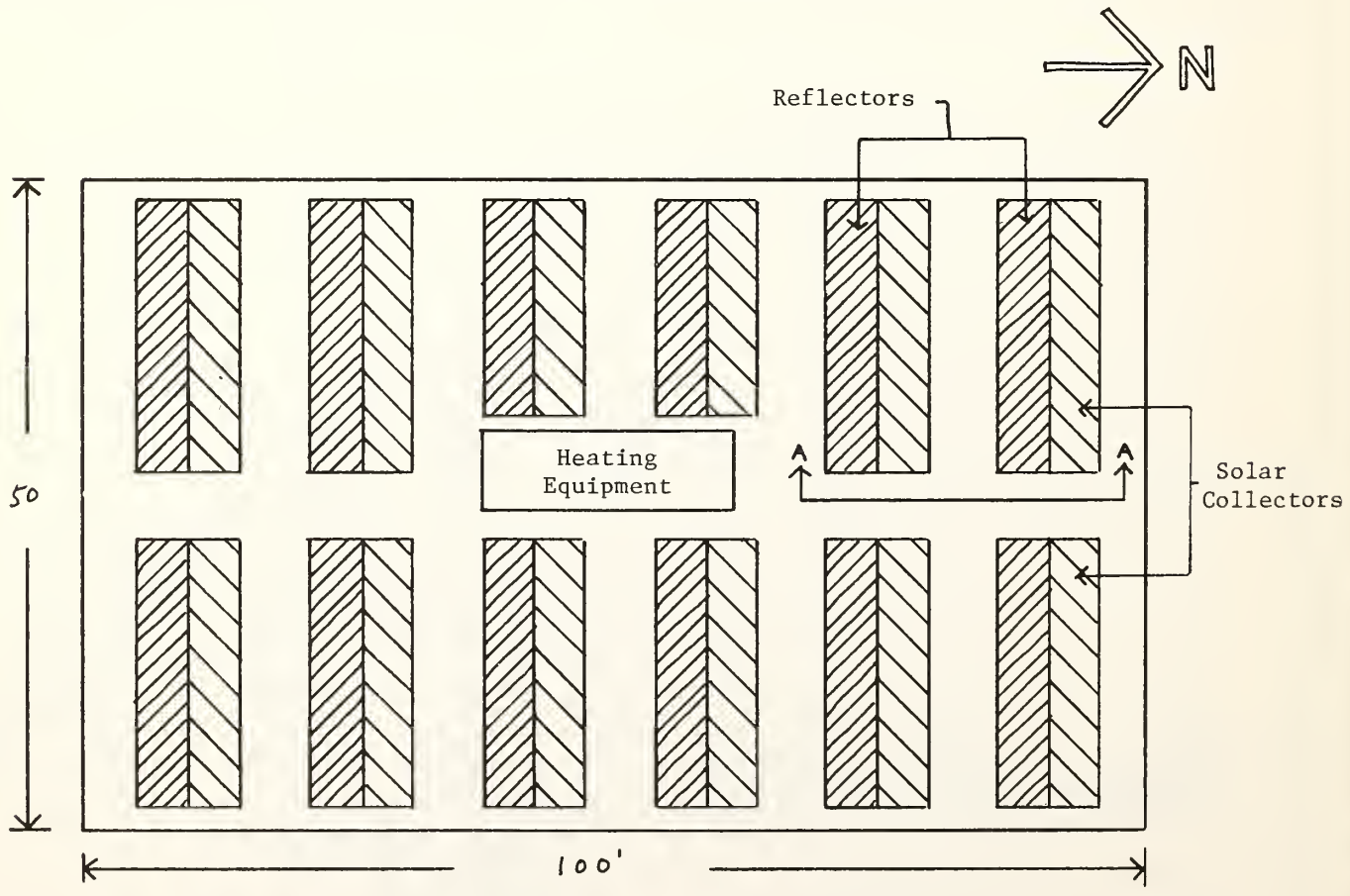
LOCATION: STAMFORD, CONN.

ROOFING MATERIAL: GRAVEL

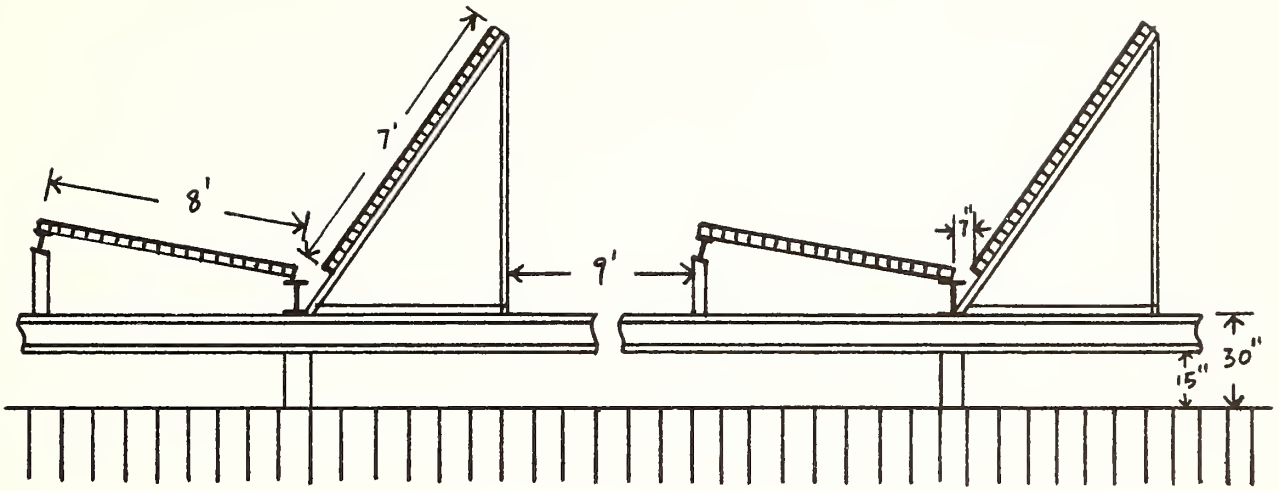
WIND EXPOSURE: WINDSWEPT

BUILDING HEATED: YES

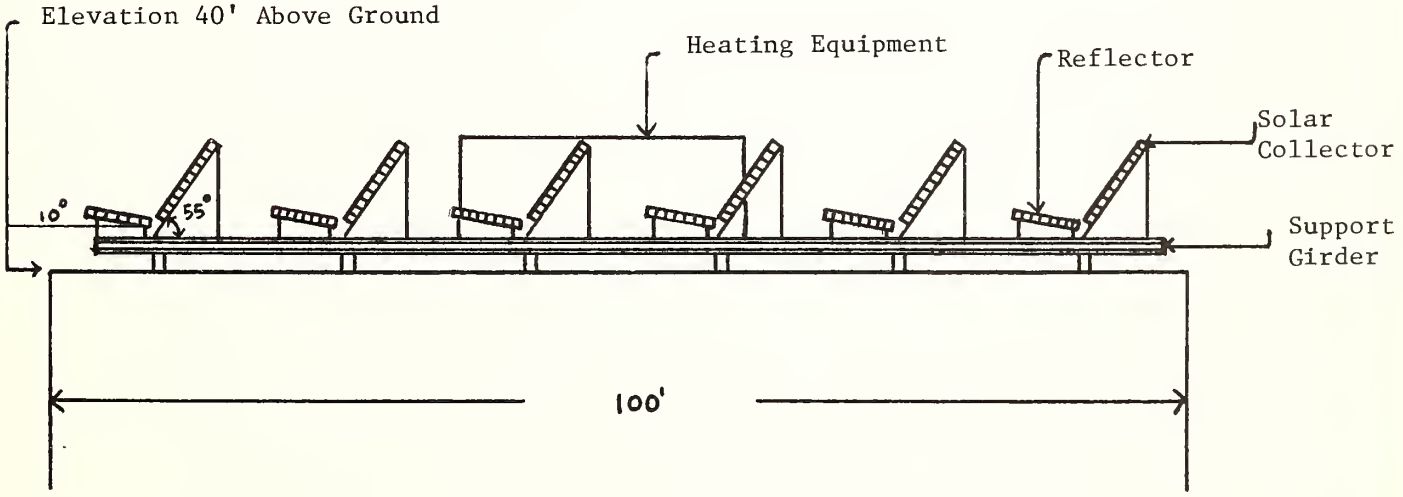
SOLAR COLLECTOR ORIENTATION: FLUSH



PLAN VIEW - LUTZ SOTIRE BUILDING



SECTION A-A EDGE VIEW OF SOLAR COLLECTORS



ELEVATION VIEW - LUTZ SOTIRE BUILDING

BUILDING: ALBIE BOOTH BOYS CLUB

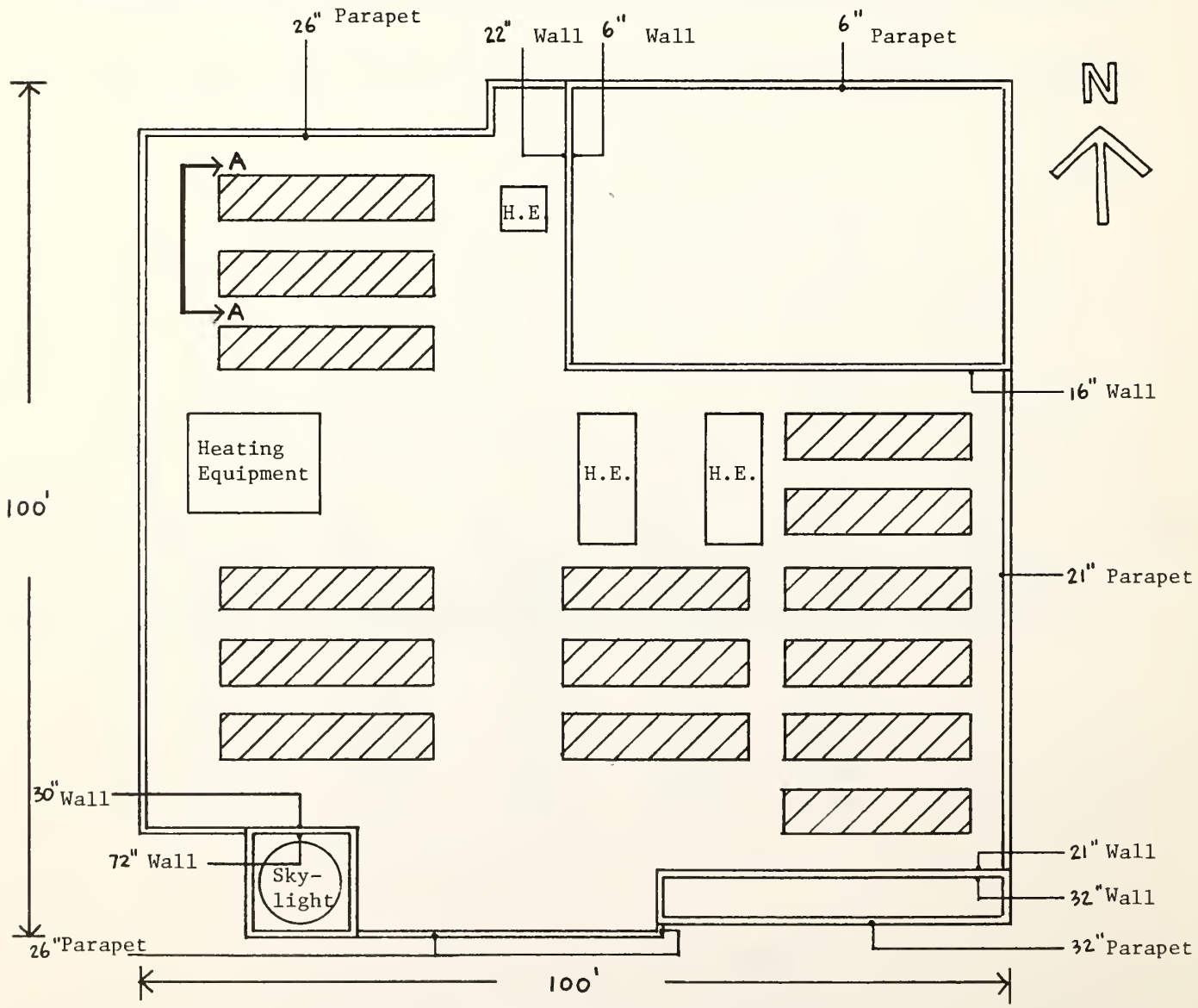
WIND EXPOSURE: WINDSWEPT

LOCATION: NEW HAVEN, CONN.

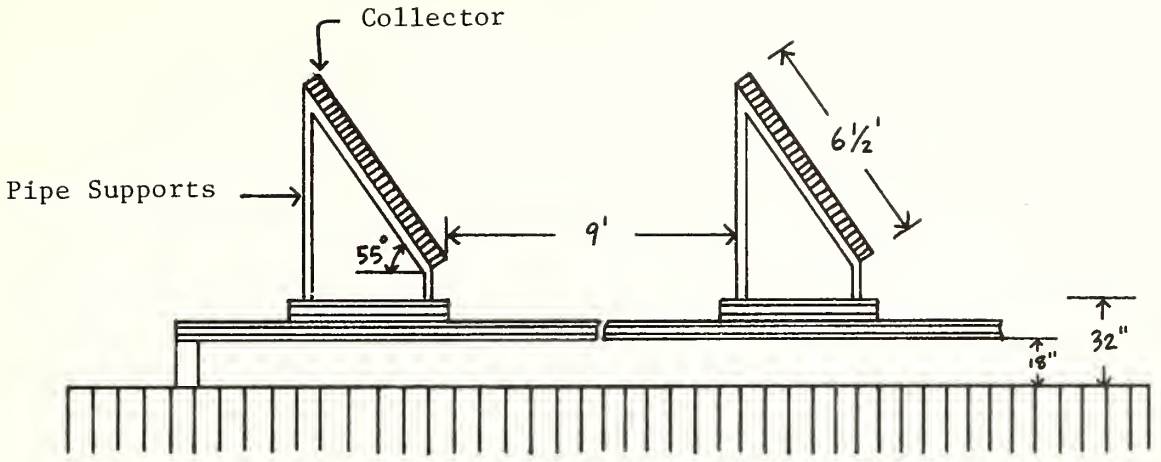
BUILDING HEATED: YES

ROOFING MATERIAL: TAR

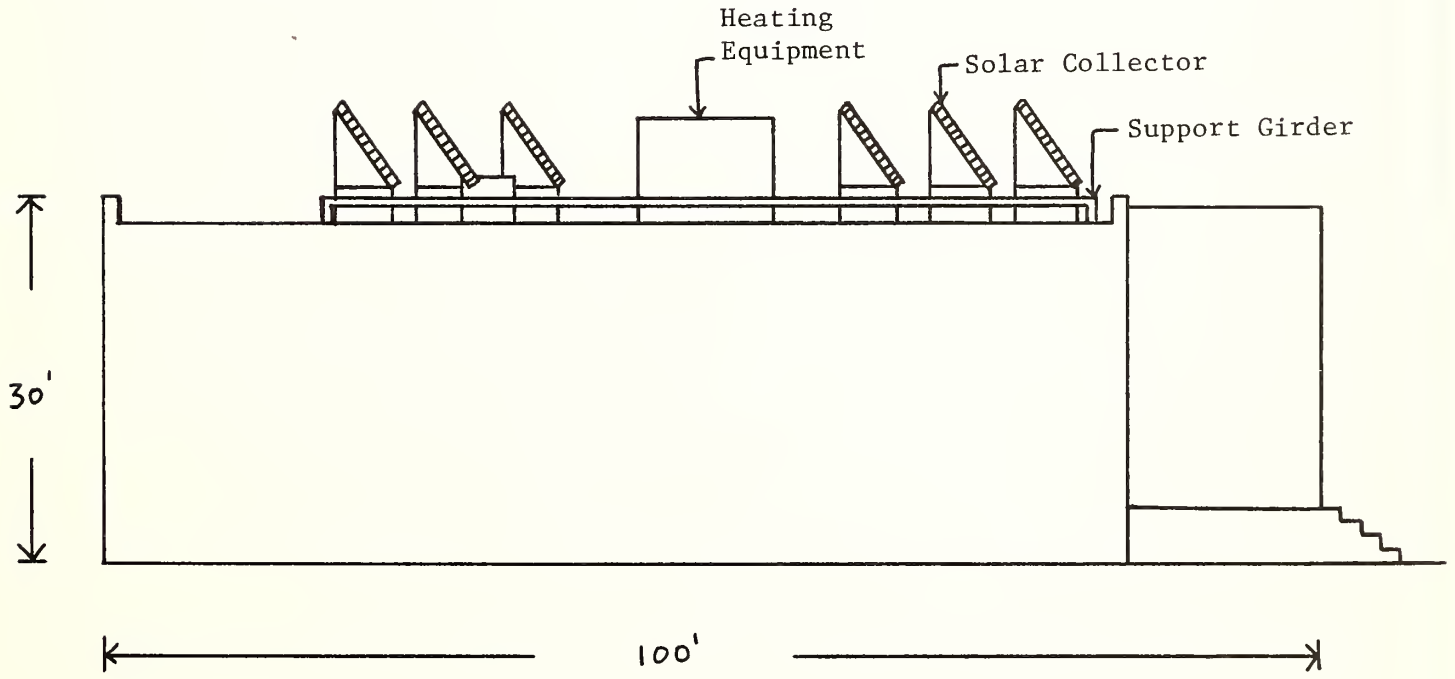
SOLAR COLLECTOR ORIGENTATION:
AT ANGLE W.R.T. ROOF



PLAN VIEW - BOYS CLUB



SECTION A-A END VIEW OF COLLECTORS



ELEVATION VIEW - BOYS CLUB

Appendix II

SNOW DENSITY SAMPLING PROCEDURE

1. Insert the sampling tube into undisturbed snow, either horizontally or vertically as conditions permit.
2. Cut away the snow from around the tube without disturbing the sample.
3. Trim the snow flush at both ends of the tube being careful not to compact or loosen the snow in the tube.
4. Clear away any excess snow on the outside of the tube.
5. Empty sample tube into a plastic bag and tie off the bag.
6. In a spot out of the wind, check to see that the pan balance is properly zeroed.
7. Weight the sample in the bag. (Because of the limited accuracy of the measurement,the weight of the bag, about 1.5 grams, can be neglected).
8. Record the sample weights and the sampling location on the data sheet.

Appendix III

Photographs

Photograph 1. SUNYA Alumni Center

Photograph 2. SUNYA Alumni Center

Photograph 3. SUNYA Alumni Center

Photograph 4. SUNYA Alumni Center

Photograph 5. Cary Arboretum

Photograph 6. Cary Arboretum

Photograph 7. Cary Arboretum

Photograph 8. Cary Arboretum

Photograph 9. Shook Residence

Photograph 10. Shook Residence

Photograph 11. Shook Residence

Photograph 12. Shook Residence

Photograph 13. Contemporary Systems

Photograph 14. Contemporary Systems

Photograph 15. Alderman Residence

Photograph 16. Alderman Residence

Photograph 17. Norris Cotton Building

Photograph 18. Norris Cotton Building

Photograph 19. Norris Cotton Building

Photograph 20. Norris Cotton Building

Photograph 21. Lutz Sotire Building

Photograph 22. Lutz Sotire Building

Photograph 23. Lutz Sotire Building

Photograph 24. Lutz Sotire Building

Photograph 25. Albie Booth Boys Club

Photograph 26. Albie Booth Boys Club

Photograph 27. Albie Booth Boys Club

Photograph 28. Albie Booth Boys Club

Appendix IV

Snow and Ice Data Sheets

SNOW & ICE DATA SHEET

BUILDING: SUNYA ALUMNI CENTER
DATE: 2/9/79
DATA COLLECTOR: P.K.

TEMPERATURE: 0°F
CLOUD COVER: SUNNY
PRECIPITATION: NONE

GROUND SNOW LOAD

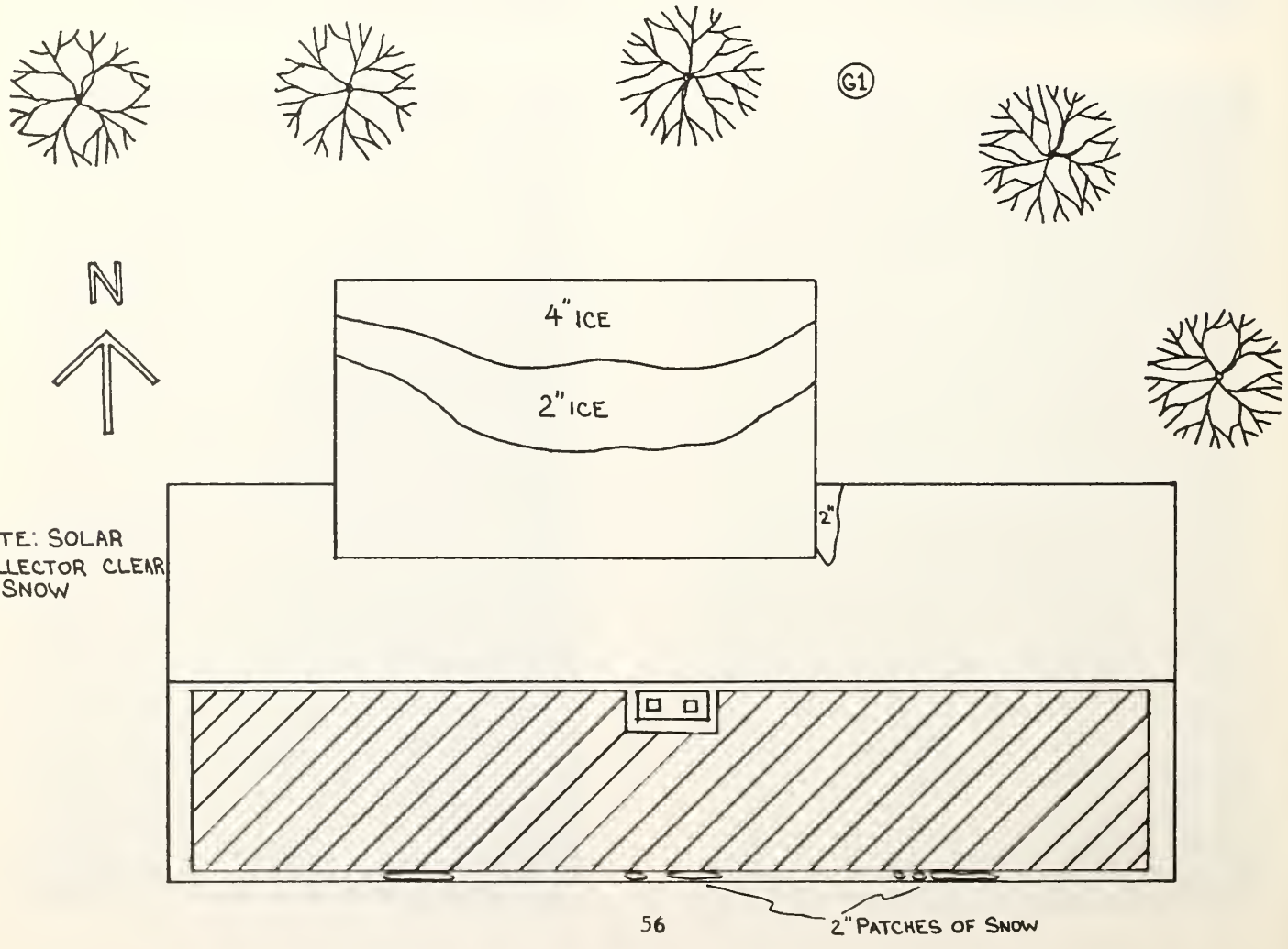
AVERAGE DEPTH: 6"

ROOF SNOW DATA

% OF ROOF COVERED: 15%
AVG. DEPTH (COVERED AREA): 3"
MAX DEPTH: 4"
MIN DEPTH: 0"

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	G1	167.4	21.1

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
NONE			



SNOW & ICE DATA SHEET

BUILDING: SUNYA ALUMNI CENTER
DATE: 2/28/79
DATA COLLECTOR: P.K.

TEMPERATURE: 40° F
CLOUD COVER: SUNNY
PRECIPITATION: NONE

GROUND SNOW LOAD

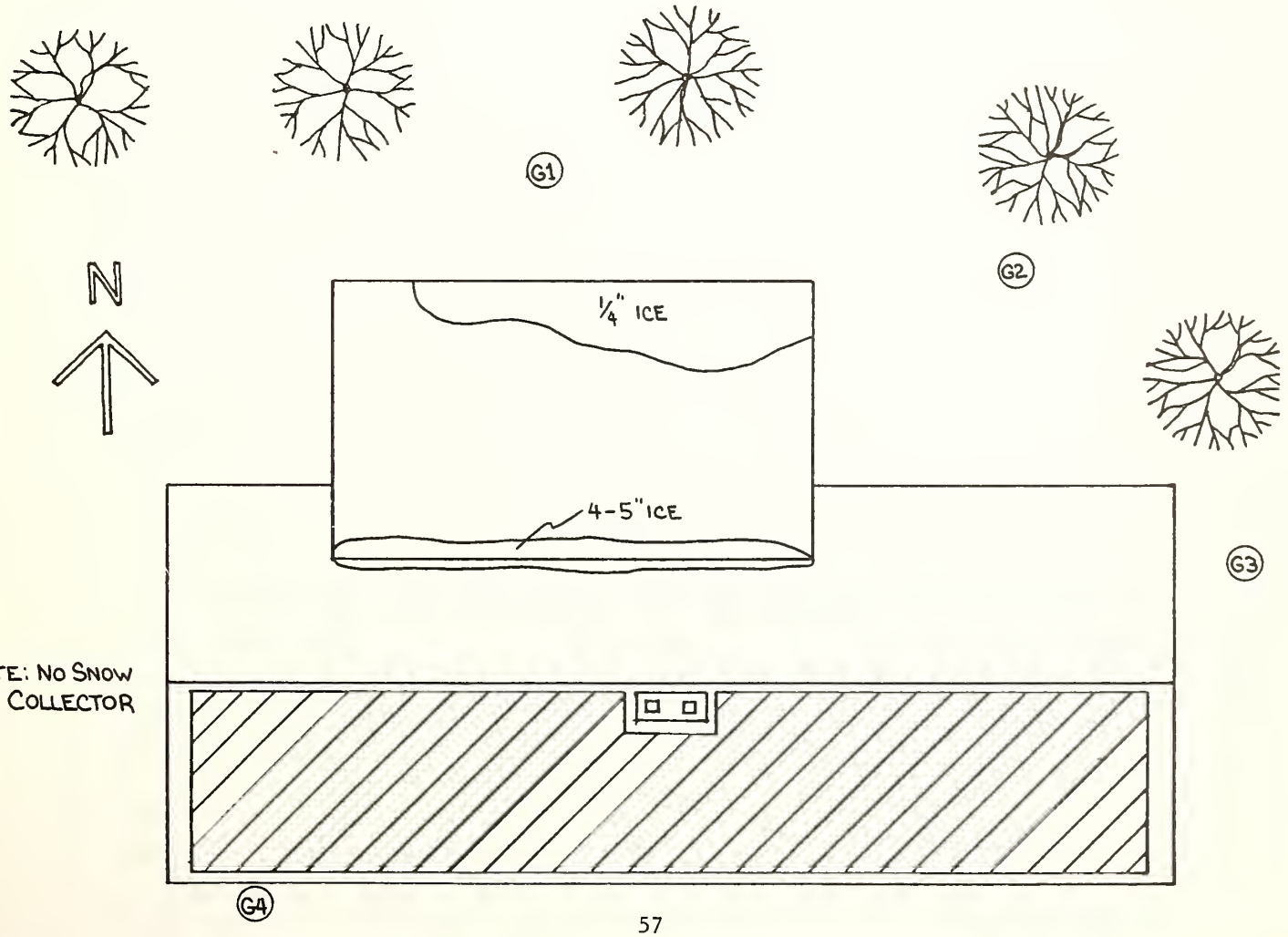
AVERAGE DEPTH: 5"

ROOF SNOW DATA

% OF ROOF COVERED: 15%
AVG. DEPTH (COVERED AREA): 2"
MAX DEPTH: 5"
MIN DEPTH: 0"

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	G1	237.4	27.9
2	G2	207.7	24.4
3	G3	212.9	25.0
4	G4	713.0	25.2

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
NONE			



NOTE: NO SNOW ON COLLECTOR

SNOW & ICE DATA SHEET

BUILDING: CARY ARBORETUM
DATE: 2/9/79
DATA COLLECTOR: P.K.

TEMPERATURE: 15°F
CLOUD COVER: SUNNY
PRECIPITATION: NONE

GROUND SNOW LOAD

AVERAGE DEPTH: 3½"

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	G1	47.3	6.0

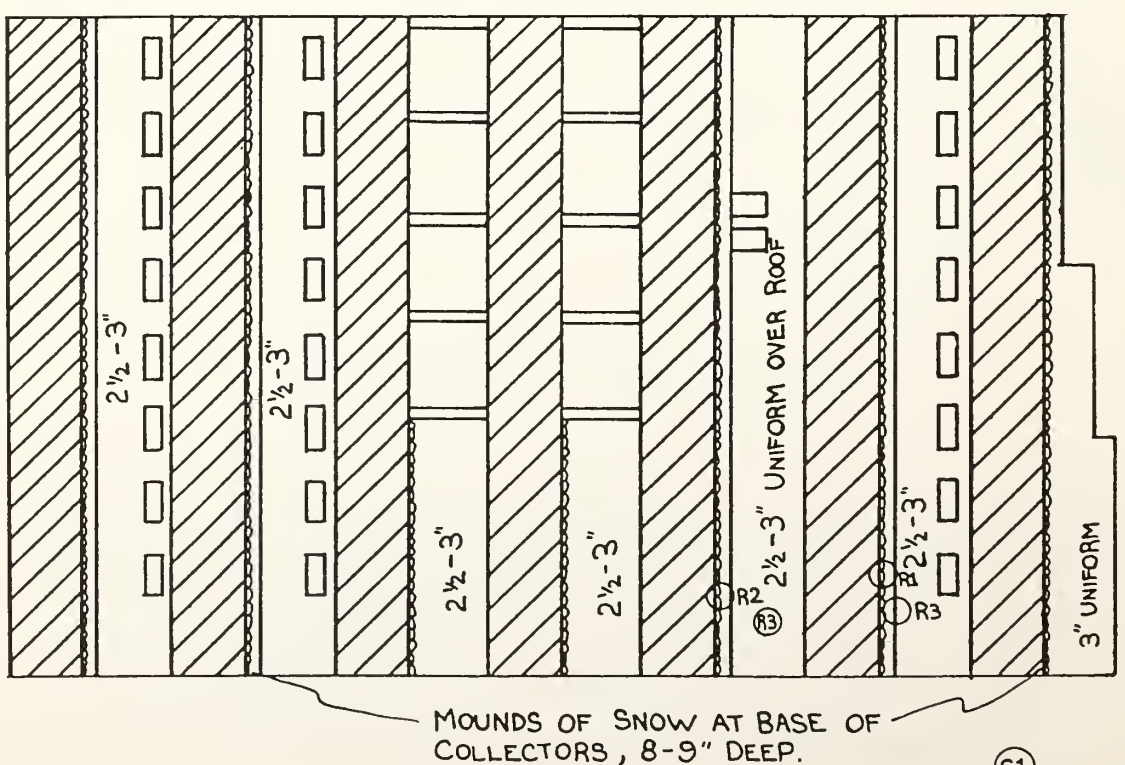
ROOF SNOW DATA

% OF ROOF COVERED: 60%
AVG. DEPTH (COVERED AREA: 3"
MAX DEPTH: 9"
MIN DEPTH: 0"

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	R1	92.7	11.7
2	R2	88.5	11.2
3	R3	78.0	9.9
4	R4	73.6	9.3

N

NOTE: NO SNOW ON SOLAR COLLECTORS



SNOW & ICE DATA SHEET

BUILDING: CARY ARBORETUM
DATE: 2/28/79
DATA COLLECTOR: P.K.

TEMPERATURE: 45°F
CLOUD COVER: SUNNY
PRECIPITATION: NONE

GROUND SNOW LOAD

AVERAGE DEPTH: 2"

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	G1	224.9	26.4
2	G2	222.5	26.2

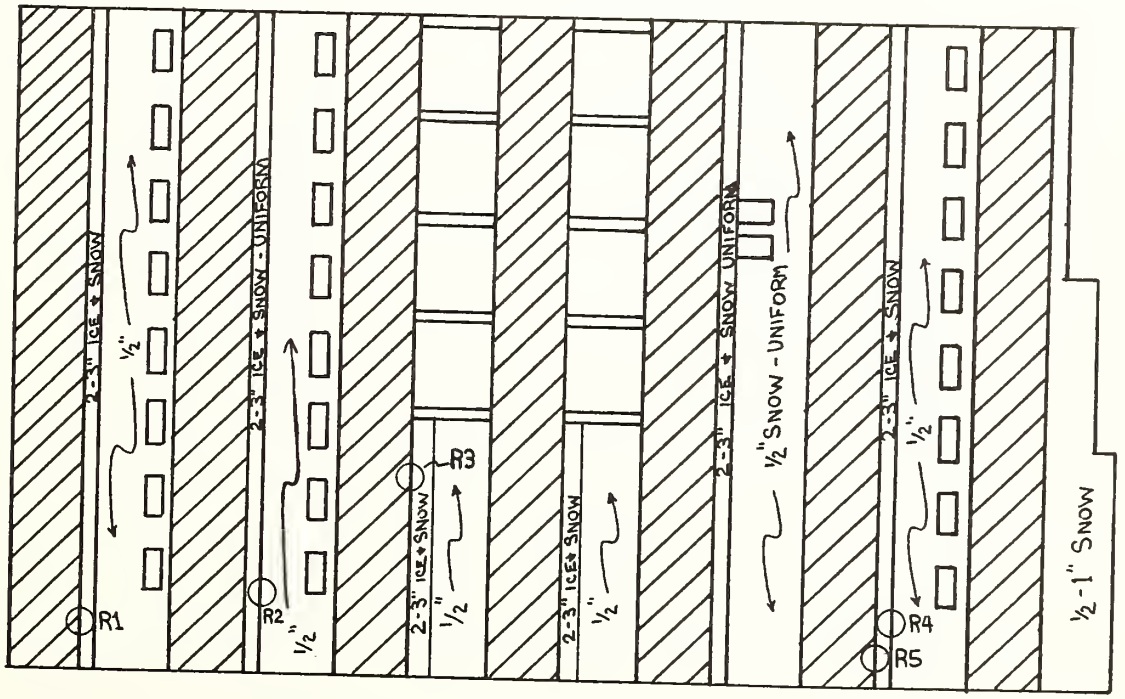
ROOF SNOW DATA

% OF ROOF COVERED: 60%
AVG. DEPTH (COVERED AREA: 1"
MAX DEPTH: 3"
MIN DEPTH: 0"

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	R1	301.9	35.5
2	R2	268.6	31.6
3	R3	302.5	35.6
4	R4	240.1	28.2
5	R5	333.9	39.3

N

NOTE: NO SNOW ON SOLAR COLLECTORS



SNOW & ICE DATA SHEET

BUILDING: SHOOK RESIDENCE
DATE: 2/9/79
DATA COLLECTOR: P.K.

TEMPERATURE: 5° F
CLOUD COVER: SUNNY
PRECIPITATION: NONE

GROUND SNOW LOAD

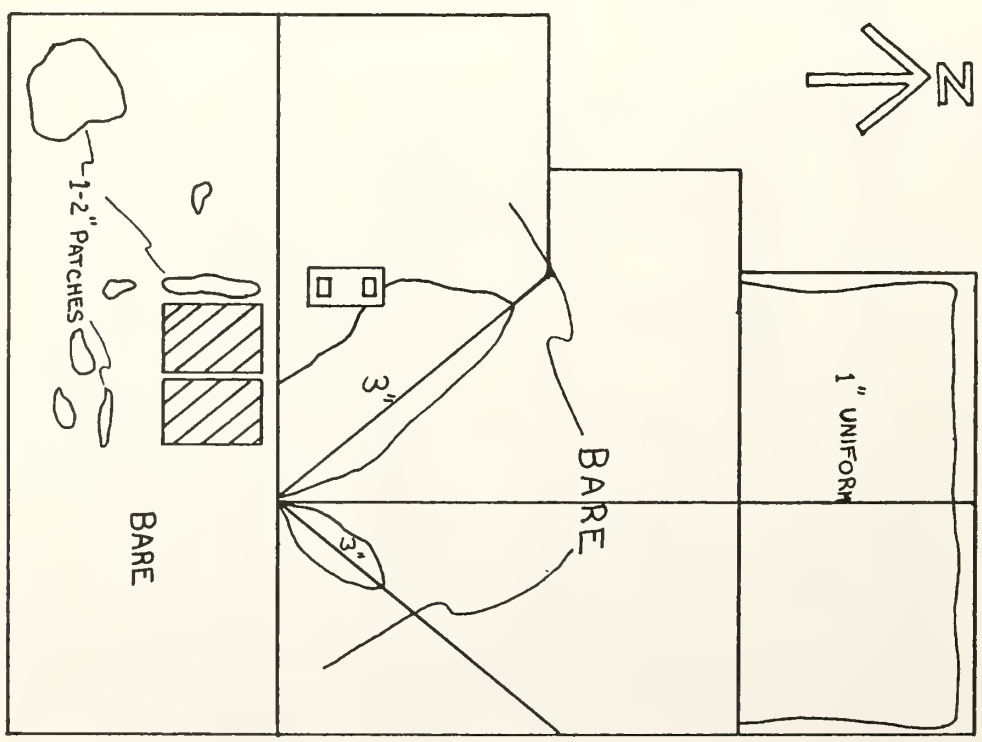
AVERAGE DEPTH: 8½"

ROOF SNOW DATA

% OF ROOF COVERED: 30%
AVG. DEPTH (COVERED AREA): 1½"
MAX DEPTH: 3"
MIN DEPTH: 0"

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)	SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	G1	161.3	20.3	NONE			

NOTE: NO SNOW ON SOLAR COLLECTORS



SNOW & ICE DATA SHEET

BUILDING: SHOOK RESIDENCE
DATE: 2/28/79
DATA COLLECTOR: P.K.

TEMPERATURE: 40°F
CLOUD COVER: SUNNY
PRECIPITATION: NONE

GROUND SNOW LOAD

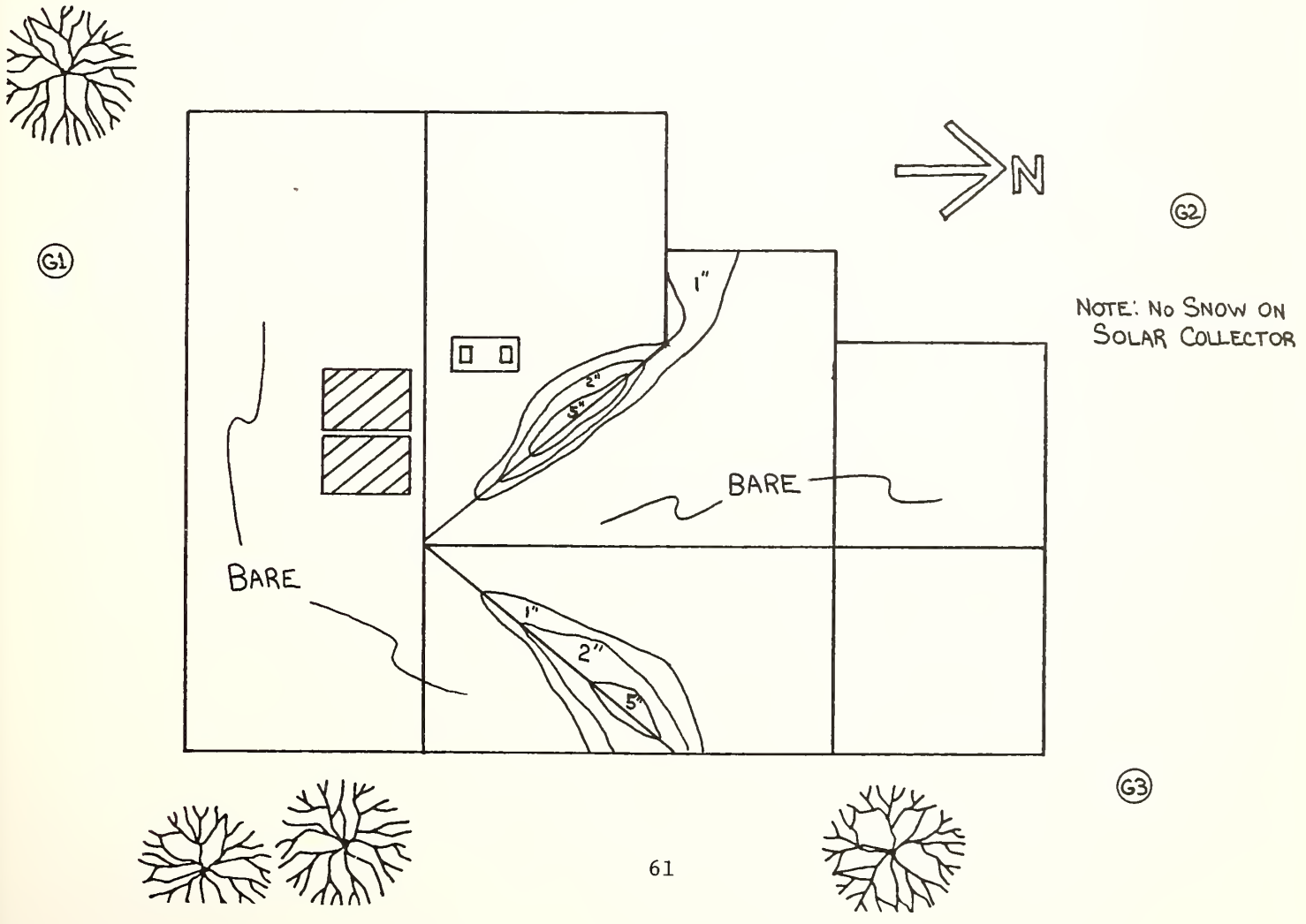
AVERAGE DEPTH: 12"

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	G1	313.8	21.8
2	G2	347.1	24.1
3	G3	389.8	27.1

ROOF SNOW DATA

% OF ROOF COVERED: 10%
AVG. DEPTH (COVERED AREA): 2"
MAX DEPTH: 5"
MIN DEPTH: 0"

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
NONE			



NOTE: NO SNOW ON SOLAR COLLECTOR

SNOW & ICE DATA SHEET

BUILDING: CONTEMPORARY SYSTEMS
DATE: 2/16/79
DATA COLLECTOR: P.K.

TEMPERATURE: 0° F
CLOUD COVER: SUNNY
PRECIPITATION: NONE

GROUND SNOW LOAD

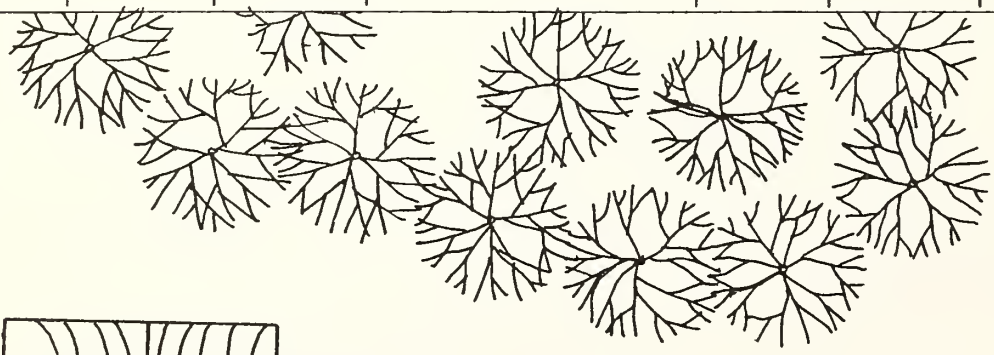
AVERAGE DEPTH: 12"

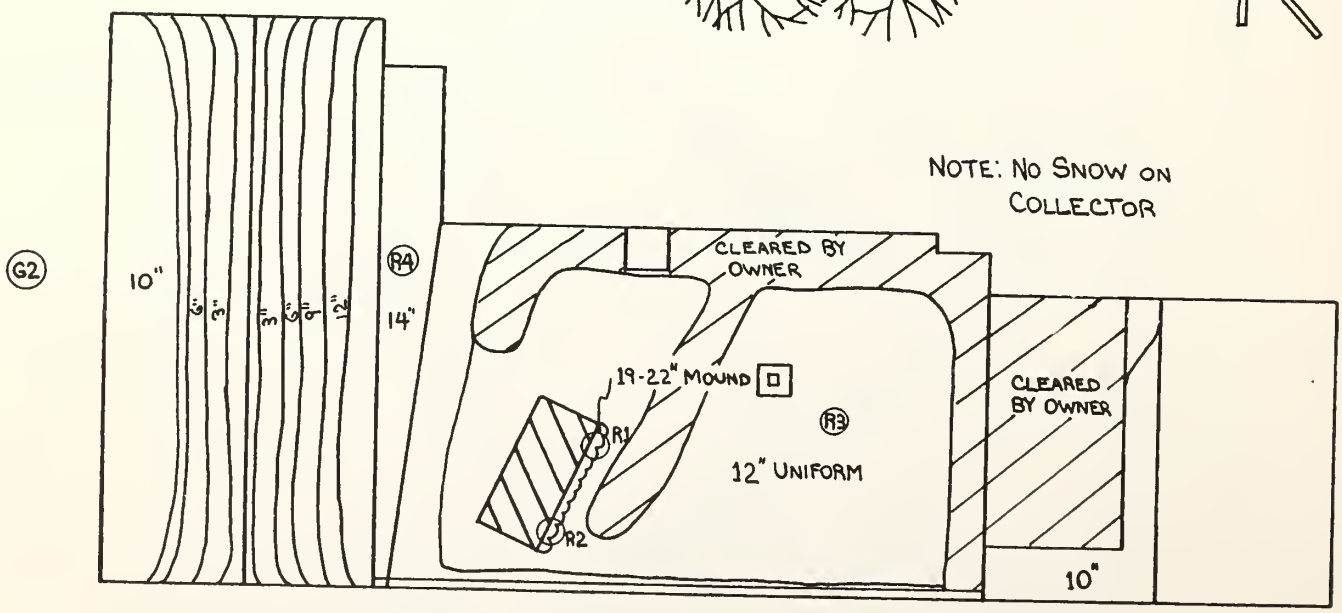
SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	G1	177.5	22.4
2	G2	146.7	18.5

ROOF SNOW DATA

% OF ROOF COVERED: 100 %
AVG. DEPTH (COVERED AREA): 11"
MAX DEPTH: 22"
MIN DEPTH: 1"

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	R1	175.5	22.1
2	R2	178.5	22.5
3	R3	170.4	21.5
4	R4	167.4	21.1





G1

SNOW & ICE DATA SHEET

BUILDING: CONTEMPORARY SYSTEMS
DATE: 3/9/79
DATA COLLECTOR: P.K.

TEMPERATURE: 45°F
CLOUD COVER: SUNNY
PRECIPITATION: NONE

GROUND SNOW LOAD

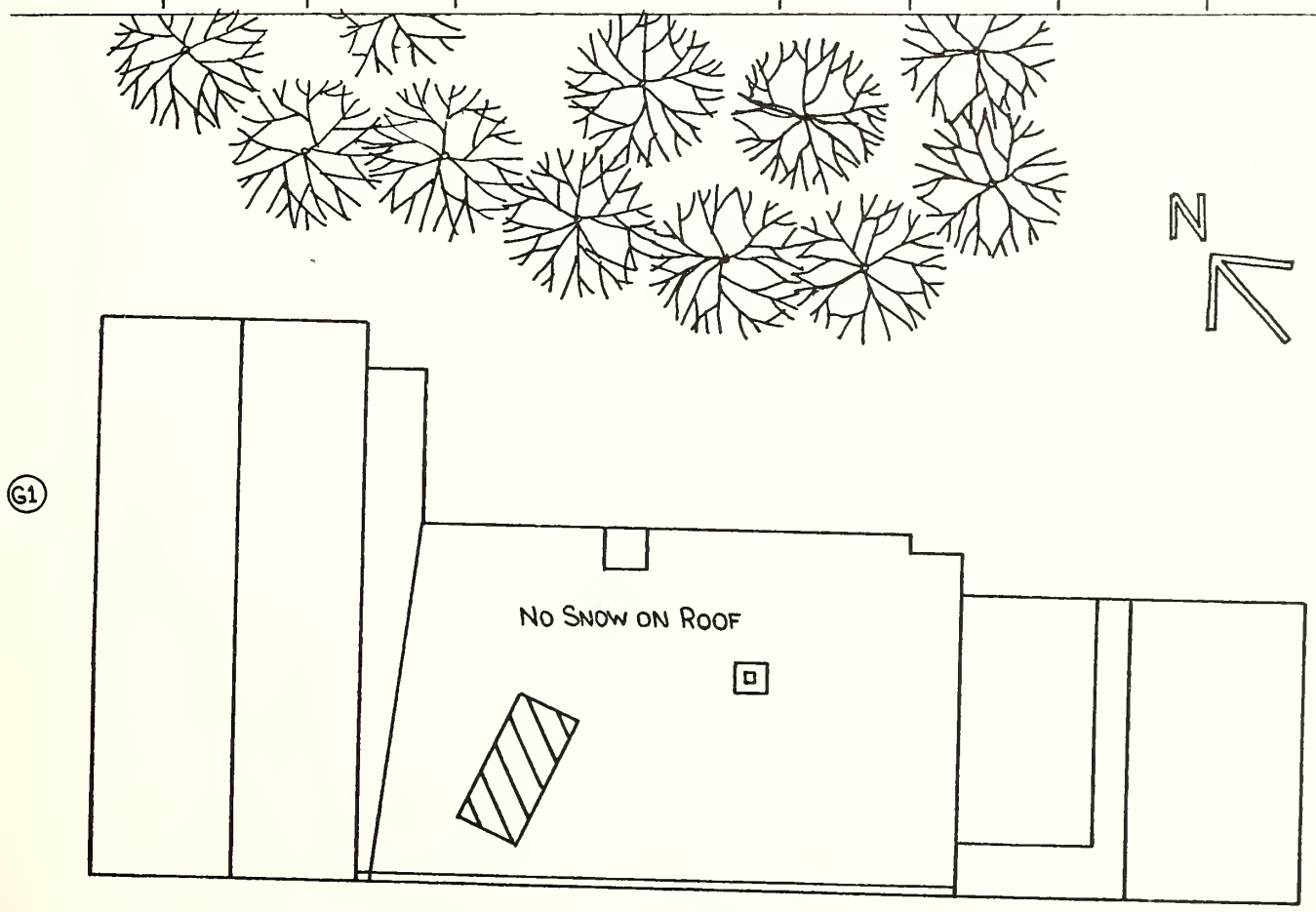
AVERAGE DEPTH: 7"

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	G1	420.9	29.3
2	G2	367.7	25.6

ROOF SNOW DATA

% OF ROOF COVERED: 0%
AVG. DEPTH (COVERED AREA):
MAX DEPTH:
MIN DEPTH:

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
NONE			



SNOW & ICE DATA SHEET

BUILDING: ALDERMAN RESIDENCE
DATE: 2/16/79
DATA COLLECTOR: P.K.

TEMPERATURE: 0°F
CLOUD COVER: SUNNY
PRECIPITATION: NONE

GROUND SNOW LOAD

AVERAGE DEPTH: 16"

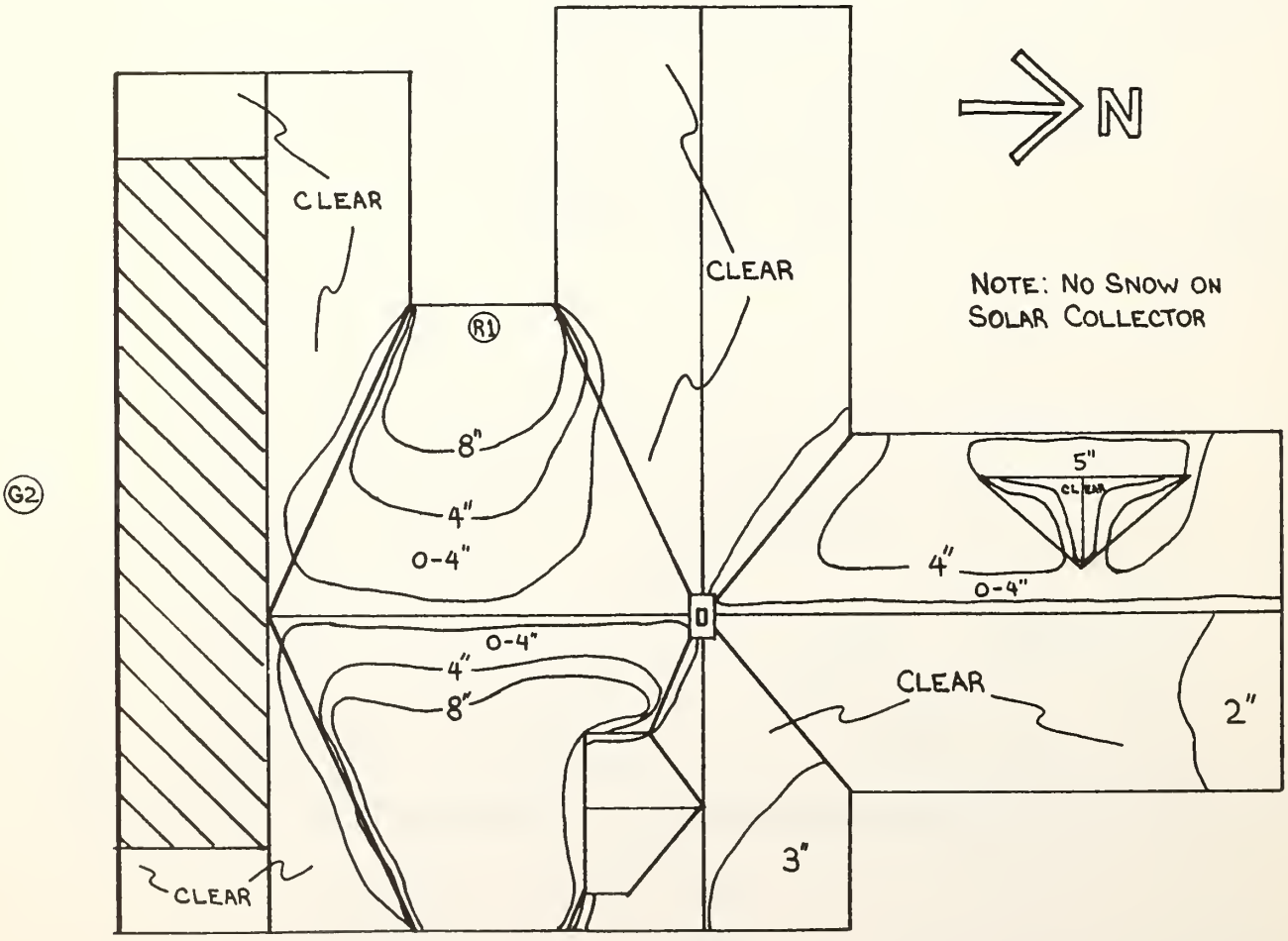
SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	G1	150.0	18.9
2	G2	145.6	18.4

ROOF SNOW DATA

% OF ROOF COVERED: 40%
AVG. DEPTH (COVERED AREA): 4"
MAX DEPTH: 8"
MIN DEPTH: 0"

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	R1	114.6	14.5

G1



G2

SNOW & ICE DATA SHEET

BUILDING: ALDERMAN RESIDENCE
DATE: 3/9/78
DATA COLLECTOR: P.K.

TEMPERATURE: 45°F
CLOUD COVER: SUNNY
PRECIPITATION: NONE

GROUND SNOW LOAD

AVERAGE DEPTH: 18"

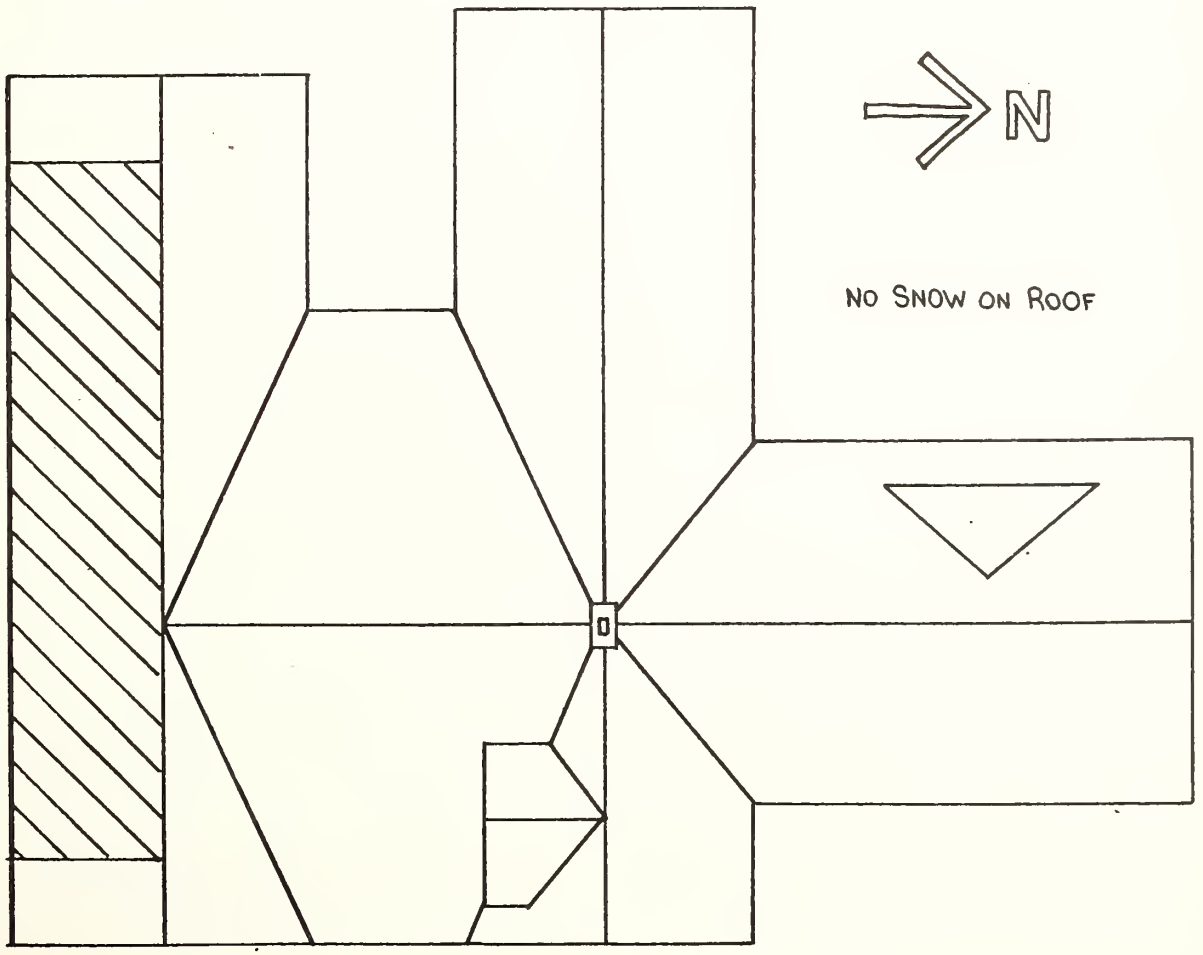
SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	G1	904.9	31.9
2	G2	890.1	31.4

ROOF SNOW DATA

% OF ROOF COVERED: 0%
AVG. DEPTH (COVERED AREA):
MAX DEPTH:
MIN DEPTH:

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
NONE			

(G1)



(G2)

SNOW & ICE DATA SHEET

BUILDING: Norris Cotton Building
DATE: 2/16/79
DATA COLLECTOR: P.K.

TEMPERATURE: 0°F
CLOUD COVER: Sunny
PRECIPITATION: None

GROUND SNOW LOAD

AVERAGE DEPTH: 5"

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	G1	175.0	22.1

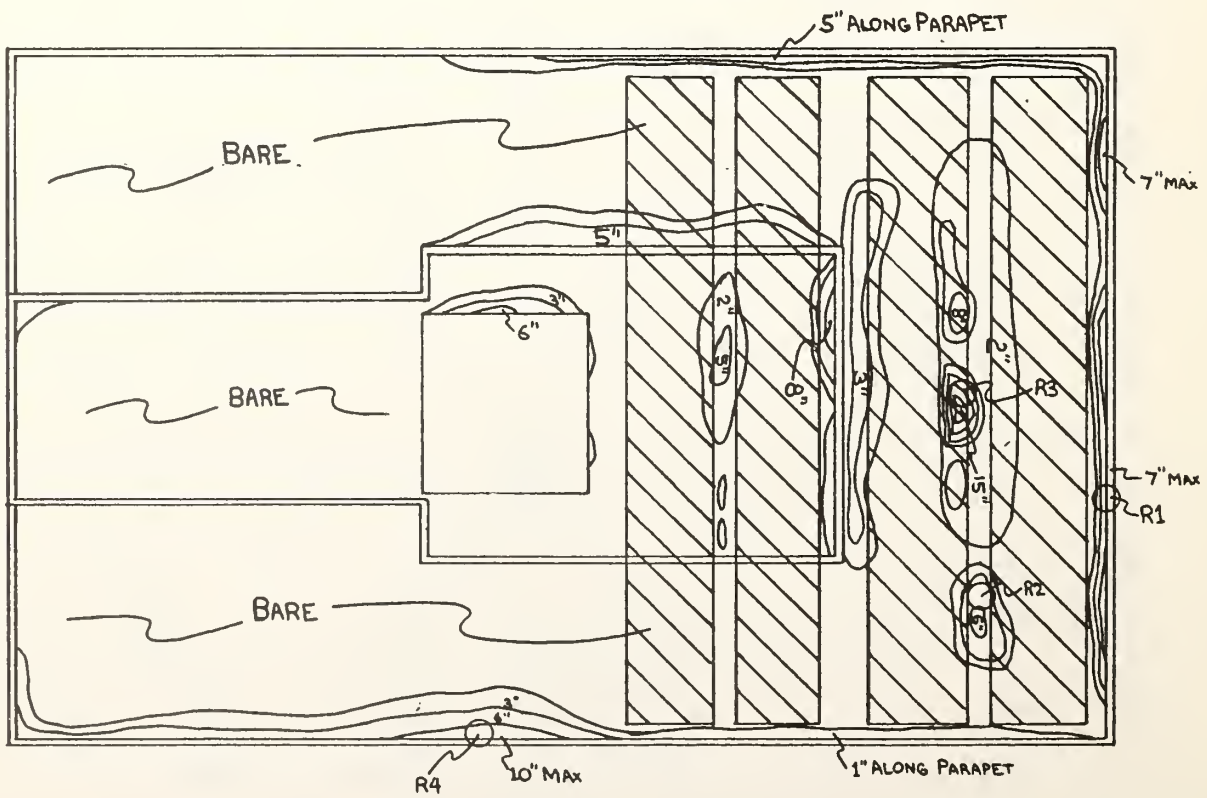
ROOF SNOW DATA

% OF ROOF COVERED: 25%
AVG. DEPTH (COVERED AREA: 3"
MAX DEPTH: 15"
MIN DEPTH: 0"

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCI
1	R1	139.9	17.6
2	R2	93.9	11.8
3	R3	178.8	22.5
4	R4	149.7	18.9

N

NOTE: No Snow on Solar Collectors



G1

SNOW & ICE DATA SHEET

BUILDING: Norris Cotton Building
DATE: 4/9/79
DATA COLLECTOR: P.K.

TEMPERATURE: 32° F
CLOUD COVER: Cloudy
PRECIPITATION: Wet Snow

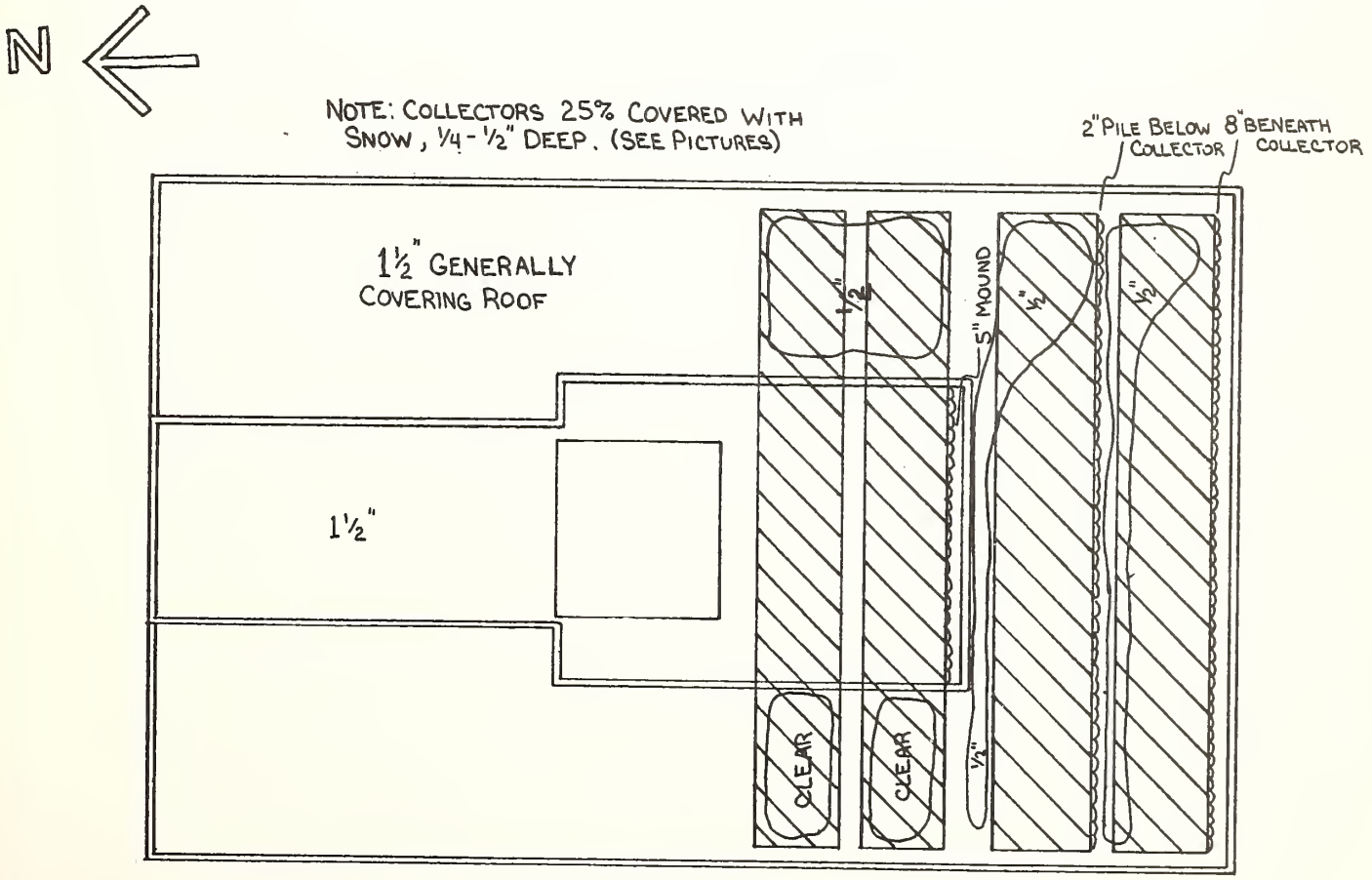
GROUND SNOW LOAD

AVERAGE DEPTH: 1½"

ROOF SNOW DATA

% OF ROOF COVERED: 95%
AVG. DEPTH (COVERED AREA: 1½"
MAX DEPTH: 8"
MIN DEPTH: 0"

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)	SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF
None				None			



SNOW & ICE DATA SHEET

BUILDING: LUTZ - SOTIRE BUILDING
DATE: 2/21/79
DATA COLLECTOR: P.K.

TEMPERATURE: 45° F
CLOUD COVER: CLOUDY
PRECIPITATION: RAIN SHOWERS

GROUND SNOW LOAD

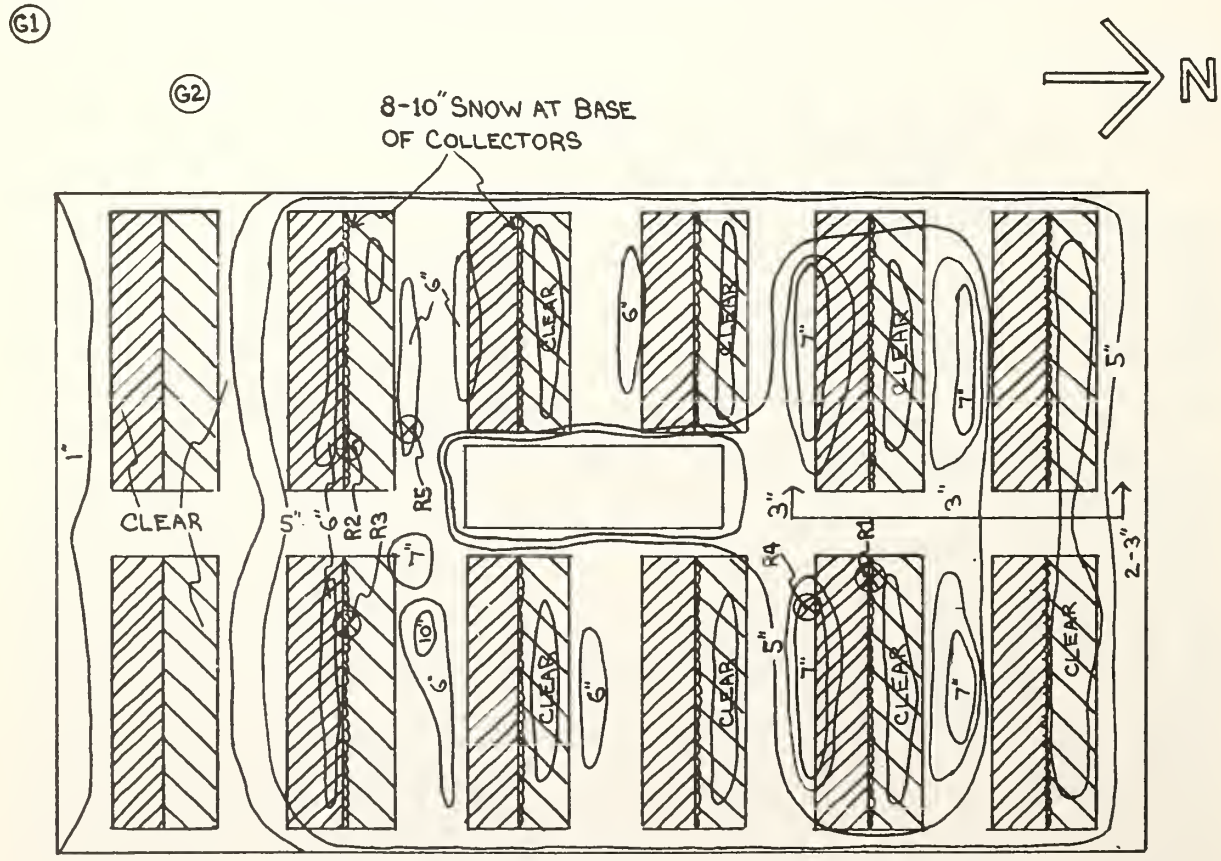
AVERAGE DEPTH: 5½ IN.

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	G1	160.2	11.8
2	G2	173.0	12.7

ROOF SNOW DATA

% OF ROOF COVERED: 80%
AVG. DEPTH (COVERED AREA): 5"
MAX DEPTH: 10"
MIN DEPTH: 0"

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	R1	216.0	15.9
2	R2	208.5	15.4
3	R3	214.5	15.8
4	R4	147.7	10.9
5	R5	165.0	12.2



NOTE: NO SNOW ON COLLECTORS, REFLECTORS ARE APPROXIMATELY 50% COVERED WITH 2-7" SNOW.

SNOW & ICE DATA SHEET

BUILDING: ALBIE BOOTH BOYS CLUB
DATE: 2/21/79
DATA COLLECTOR: P.K.

TEMPERATURE: 45° F
CLOUD COVER: CLOUDY
PRECIPITATION: RAIN

GROUND SNOW LOAD

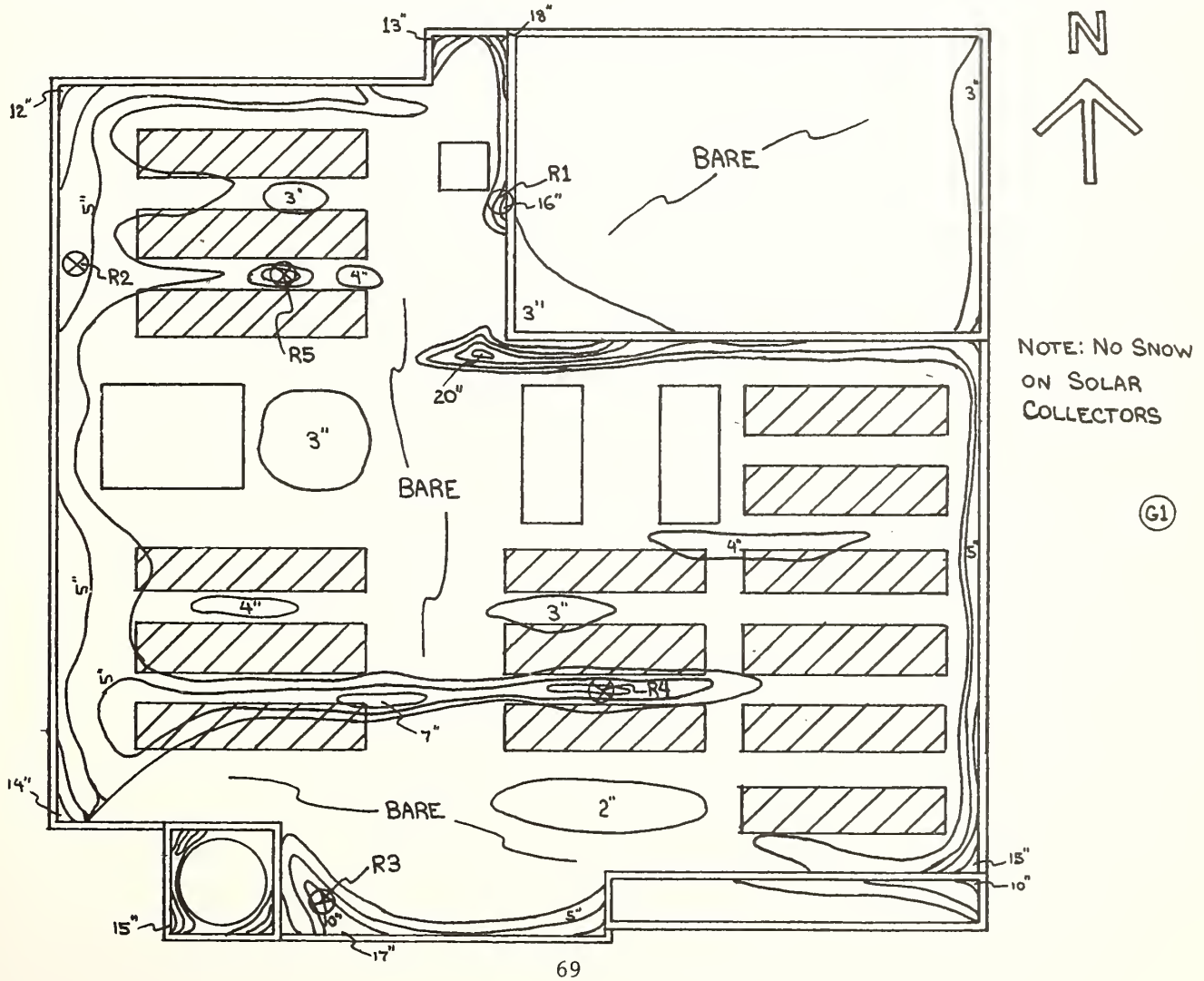
AVERAGE DEPTH: 3 IN.

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	G1	210.4	15.5

ROOF SNOW DATA

% OF ROOF COVERED: 20%
AVG. DEPTH (COVERED AREA): 5"
MAX DEPTH: 20"
MIN DEPTH: 0"

SAMPLE	LOCATION	WT (GMS)	DENSITY (PCF)
1	R1	213.9	15.8
2	R2	194.1	14.3
3	R3	211.8	15.6
4	R4	202.0	14.9
5	R5	214.0	15.8



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Michael J. O'Rourke

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14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES The report presents the results of a contract study conducted for NBS. Any conclusions, opinions, or interpretations contained herein are the responsibility of the authors of this report.

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report presents observations on and measurements of snow and ice on eight structures with flat plate solar collectors mounted on the roof. The data was collected from January through March of 1979 in areas of New York, New Hampshire and Connecticut in the general vicinity of Albany, New York. Half the installations had the collectors mounted flush with the roof surface, while the remainder had collectors mounted on racks at an angle to the roof. Contours of snow depth on the roof, snow densities, measurements of snow on the ground adjacent to the buildings, sketches and photographs of the roofs, and comments of the owners of the installations are included in the report, in addition to a discussion of the state of the art of predicting snow accumulation on roofs of buildings. The effect of solar collectors on the design of roof structures for the support of snow loads is discussed and recommendations for future research are made.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Building; ice; load; roof; roof load; snow; solar collector; structural engineering.

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